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SOME PHYSIOLOGIC COMPARISONS

OF MALE AND FEMALE STUDENTS

BY



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A THESIS

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ABSTRACT

The purpose of this study was to make a comparison between male and female students on the following variables: age, height and weight; body composition; maximal oxygen consumption measured in l./min., ml./min./kg. and ml./min./kg. fat free; and PWC₁₇₀ measured in KPM/min., KPM/min./kg., and KPM/min./kg. fat free.

Twenty-four healthy male and twenty-four healthy female students randomly selected from the population of first year undergraduate students enrolled in the Faculty of Physical Education, the University of Alberta, participated in the study. Each student underwent a series of tests including: two Mitchell, Sproule and Chapman MVO₂ tests, an Astrand bicycle MVO₂ test, two modified Sjostrand PWC₁₇₀ tests, two gradational step tests, and body densitometry measures.

It was concluded that significant differences, at the .05 level of significance, occurred between the male and female students for all the variables studied, including the maximal and submaximal tests in which measures considering fat free body composition were used. In addition, significant differences at the .05 level of significance, were found between the Mitchell, Sproule and Chapman, and the Astrand tests; and between the modified Sjostrand PWC₁₇₀ and the gradational PWC₁₇₀ step tests; for both the males and females.

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CHAPTER I

STATEMENT OF THE PROBLEM

INTRODUCTION

Astrand states "It is well known that the physical working capacity is less for females than for males, . . . and our present knowledge of the physiological basis of these differences, and of the limiting factors in working capacity is incomplete." (4) Relatively few studies have been conducted in which the material consisted of both male and female undergoing identical tests.

Metheny, et al. (30) using a treadmill test for measuring maximal oxygen consumption found a mean maximal oxygen uptake measured in cc./min./kg. of 40.9 for women and 51.3 for the men in their study. Astrand (4) made a comparison of a large number of both male and female subjects and found in the age range 16-18 mean maximal oxygen uptake values, measured in cc./min./kg. for women of 47.2 and for men of 57.6. In the age range 20-25 he found values of 48.4 for women, and 58.6 for men. In further studies Astrand, et al. (7) found the mean maximal oxygen uptake for women was 2.60 and for men 4.05, measured in litres per minute.

There have been many studies comparing oxygen uptake, both maximal and submaximal, with body composition. (4, 10, 13, 29, 32, 37, 41, 51.) According to these sources maximal oxygen uptake and oxygen uptake correlate fairly highly with body weight, usually in the neighbourhood of $r=0.7$. In some cases maximal oxygen uptake was compared with body weight minus fat (10, 13, 37, 51) with significant correlations being found. In all but one (37) the correlation of maximal oxygen uptake with fat free body weight was found to be higher than the correlation of maximal oxygen

uptake and body weight.

Body composition has been studied by many researchers. (8, 9, 26, 28, 30, 32, 47.) Where comparisons between the sexes have been made it is generally accepted, as stated by Ljunggren (26), that 20-30 percent of the body weight in normal women and 10-20 percent of the body weight in normal men is composed of fat.

THE PROBLEM

The purpose of this study was to make a comparison between male and female on the following variables:

1. Age, Height, and Body Weight.
2. Body Composition
 - A. Percent Body Fat.
 - B. Fat Free Body Weight.
3. Maximal Oxygen Consumption
 - A. Mitchell, Sproule and Chapman Test
 - i. l./min.
 - ii. ml./min./kg. Body Weight.
 - iii. ml./min./kg. Fat Free Body Weight
 - B. Astrand Bicycle Test
 - i. l./min.
 - ii. ml./min./kg. Body Weight.
 - iii. ml./min./kg. Fat Free Body Weight.
4. Physical Work Capacity 170
 - A. Modified Sjostrand Test
 - i. KPM/min.
 - ii. KPM/min./kg. Body Weight.

4. Physical Work Capacity 170

A. Modified Sjostrand Test

iii. KPM/min./kg. Fat Free Body Weight.

B. Progressive Step Test

i. KGM/min.

ii. KGM/min./kg. Body Weight (Meters/min.).

iii. KGM/min./kg. Fat Free Body Weight.

Note: Results will be computed using a mean of the results of two trials for the Mitchell, Sproule and Chapman: Modified Sjostrand; and Progressive Step Tests.

MAIN HYPOTHESES

The null hypothesis asserts that no significant differences exist at the .05 level of significance between male and female for maximal oxygen uptake and physical work capacity 170 when scores are expressed in terms of fat free body weight.

The alternate hypothesis asserts that significant differences do exist at the .05 level of significance between male and female for maximal oxygen uptake and physical work capacity 170 when scores are expressed in terms of fat free body weight.

SUBSIDIARY HYPOTHESES

The null hypotheses assert that no significant differences exist at the .05 level of significance between male and female for the variables: age, height, and body weight; body composition; maximal oxygen consumption; and physical work capacity 170.

The alternate hypotheses assert that significant differences do

exist at the .05 level of significance between male and female for the variables: age, height, and body weight; body composition; maximal oxygen consumption; and physical work capacity 170.

JUSTIFICATION FOR STUDY

Physiologic bases are necessary for the planning of rational training and practice, and for a sound choice of events with regard to the participant's sex.

There have been very few studies making such a comparison where fat free body weight has been included and where the data was collected on two similar groups of males and females each undergoing the same series of tests.

There is also the intangible reason that people are interested in this type of comparison.

DELIMITATIONS OF STUDY

The study was confined to forty-eight subjects selected at random from the first year undergraduate students enrolled in the Faculty of Physical Education, the University of Alberta.

The study was limited to the following variables: Age, Height, Body Weight, Body Composition, Maximal Oxygen Uptake, and Physical Work Capacity 170.

LIMITATIONS OF STUDY

The reliabilities of the methods tested and the reliabilities and limitations of the equipment utilized.

The statistical procedures used to analyze the data.

The magnitude of experimental error by the investigator

The variations in temperature and humidity in the laboratory.

DEFINITION OF TERMS

Kilopond Meter (KPM) - one kilopond meter is the force acting on the mass of one kilogram at the normal acceleration of gravity.

Kilogram Meter (KGM) - one kilogram meter is the force required to raise a one kilogram mass through one meter.

Note: According to Shephard (44) on earth 1 KPM = 1 KGM.

Fat Free Body Weight - the weight of the body if the amount of fat within the body, calculated using underwater weight, is subtracted from the total body weight.

Maximal Oxygen Uptake - a test "of the maximal capacity of the cardiovascular-respiratory system to take up, transport and give off oxygen to the working tissues and for these tissues to use the oxygen."
(20)

Physical Work Capacity 170 (PWC 170) - the amount of work an individual can perform at a steady state heart rate of 170 beats per minute measured in KPM or KGM.

Steady State Heart Rate - the heart rate between two successive readings, taken at one minute intervals, which does not differ by more than $\pm$ five beats.

CHAPTER II

REVIEW OF THE LITERATURE

MAXIMAL OXYGEN CONSUMPTION AND BODY COMPOSITION

Seltzer (41) in a study of 34 male students, (mean age 26.82 years, range 20-30 years; mean body weight 72.31 kg., range 54.7-93.4 kg.) compared oxygen uptake, as measured on a treadmill test, with a number of anthropometric measurements. He concluded that "there appears to be a relation of a constitutional nature between morphology of individuals and their consumption of oxygen." (41) He found that maximal oxygen uptake per minute correlated $r = 0.88$ with weight.

Mahadeva, Passmore, and Woolf (29) investigated the relationship between energy expenditure, during a step and walking test; and weight, height, sex, and race. They found that the metabolic cost of standardized stepping and walking, determined in 50 subjects, was linearly proportional to body weight. They found no significant increase in the precision of individual assessment was gained by taking into account height, age, sex, race, or resting metabolism. The authors concluded that energy expenditure can be taken as directly proportional to body weight." (29)

Astrand (4) in his studies of physical working capacity in relation to sex and age found a correlation between maximal oxygen uptake and body weight of $r = 0.98$ in a sample of 115 males, aged 4-33. In a sample of 76 females, weighing greater than 40 kg., and from 12-25 years old, he found a correlation of $r = 0.87$ between maximal oxygen uptake and body weight. In a sample of 36 young girls 4-25, weighing less than 40 kg., he found a correlation of $r = 0.98$ between maximal oxygen uptake and body weight.

Buskirk and Taylor (10) in testing a group of 59 young college students and soldiers (no other details of sample given) found the following correlation: maximal oxygen consumption with body weight $r = 0.63$, with fat free body weight $r = 0.85$, with 'active tissue' $r = 0.91$, and with blood volume $r = 0.78$. 'Active tissue' was defined as body weight minus estimated body fat, thiocyanate space, and bone mineral. Also in this study, Buskirk and Taylor compared 3 groups of 9 relatively sedentary students, classified according to the percentage of body fat (less than 10, 10-25, and 25 and above) with respect to the maximal oxygen consumption per minute per kilogram of fat free body weight. They found no significant difference between the groups.

Miller and Blythe (32) tested 48 subjects, (physical education students and medical students, mean age 24.3 years, range 18-35 years; mean weight 82.3 kg., range 53.9-136.4 kg.) on a submaximal treadmill test. They found a correlation between oxygen consumption and body weight of $r = 0.75$, and body weight minus fat minus bone of $r = 0.67$.

Von Döbeln (16) tested 33 male and 32 female subjects (no further information available on sample) on a maximal oxygen uptake test. He correlated this with $(\text{weight minus adipose tissue})^{2/3}$ and found a correlation of $r = 0.756$. To get the exponent $2/3$, von Döbeln plotted maximal oxygen uptake versus weight minus adipose tissue. From this he calculated the best regression line of the logarithmic values, and from this he found the value of the exponent to be 0.71. This is close to the theoretical value predicted by Hill that power will be approximately constant per unit body weight raised to a power close to $2/3$.

Welch, et al. (51) tested 28 young men, (mean age 23.7 years, $SD \pm 1.9$ years, range 21-28 years; mean body weight 75.3 kg., $SD \pm 9.6$ kg.,

range 61.4-98.6 kg.), for maximal oxygen uptake in the manner described by Taylor, et al. (50), and determined the body fat content by means of hydrostatic testing. They found significant correlation (P greater than 0.01) between maximum oxygen consumption measured in litres per minute and body weight $r = 0.59$, body weight minus fat $r = 0.65$, and body weight minus fat minus bone $r = 0.64$. Welch, et al. found that maximum oxygen uptake measured in cubic centimeters per minute per kilogram of body weight was significantly affected by the percentage of body fat; however, when expressed as litres per minute or cubic centimeters per minute per kilogram of fat free weight, it was not significantly affected by the percentage of body fat.

Rasch and Pierson (37) measured oxygen consumption in 21 male students, with an average weight of 73.95 kg., by means of a walk on a treadmill. Oxygen consumption was correlated with body weight, fat free body weight, height, and various indices of body build. The only significant correlation (P greater than 0.01) was between body weight and oxygen consumption where an $r = 0.65$ was found.

Coyne (13) compared maximal oxygen uptake of 30 active males, (age 23.1 years $SD \pm 4.3$ years, range 19-34 years; mean weight 75.05 kg., $SD \pm 7.2$ kg., range 59.5-88.1 kg.), as determined by treadmill running, with body weight, total body fat, and fat free body weight. He found that fat free body weight correlated $r = 0.39$ ($P = 0.05$) with the maximal oxygen uptake. Body weight and body fat did not show a statistically significant relationship with maximal oxygen intake.

Table I presents a comparison of the results discussed on studies of body composition and maximal oxygen uptake.

TABLE I

COMPARISON OF RESULTS OF EXPERIMENTS ON BODY COMPOSITION AND MVO_2

	SELTZER 1940	ASTRAND 1952				MILLER & BLYTHE 1952		BUSKIRK & TAYLOR 1954	VON DOBELN 1956	WEICH, et al. 1958	RASCH & PIERSON 1962	COYNE 1963
Sample Size	34 m	115 m	76 f	36 f	48 m	59 m	33 f	28 m	21 m	30 m		
Sample Age (years)	26.82				24.3			23.7		23.1		
Mean S.D. Range	20-30	4-33	12-35	4-25	18-35			1.9		4.3		
								21-28		19-34		
Sample Body Weight (kg.)	72.31		40+	40 -	82.3			75.4	73.95	75.05		
Mean S.D. Range	54.7-93.4				53.9-136.4			9.6		7.2		
								61.4-98.6		59.5-88.1		
<u>OXYGEN CONSUMPTION VS.</u> (r =)												
Body weight, kg.	0.88	0.98	0.87	0.96	0.75	0.63		0.59	0.65	0.26 *		
Body weight minus fat, kg.						0.85		0.65	0.54**	0.39**		
Body weight minus fat minus bone, kg.					0.67			0.64				
Body weight minus fat minus bone minus extracellular fluid, kg.						0.91						
(Body weight minus adipose tissue) ^{2/3} , kg.							0.76					

* correlation not significant at .05 level

** correlation not significant at .01 level

MAXIMAL OXYGEN CONSUMPTION OF MALES AND FEMALES

Metheny, et al. (30) studied 17 women, ages 19-27; and 30 men, ages 19-23. The test consisted of running at seven m.p.h. at a 8.6 percent grade for 5 minutes or until unable to continue. The mean maximal oxygen uptake measured in cc./min./kg. was 40.9 for the women with a range of 29.6-47.5; and 51.3 for the men with a range of 30.5-60.5. The mean maximal heart rate for women was 197/minute and for the men 194/minute. The authors concluded from their results "that women as a group are the 'weaker sex' being less fit than men for both moderate and strenuous exertion and exhibiting less endurance for this type of activity." (30)

Astrand (4) in his studies compared males and females from age 4 to 33. Table II presents his results of maximal oxygen uptake as determined on a bicycle ergometer for the age groups 16-33.

TABLE II

MEAN MVO₂ VALUES FOR TOTAL, AND PER KG. BODY WEIGHT
FOR DIFFERENT AGE GROUPS (4)

Age	Sex	Number	MVO ₂ (l./min.)	MVO ₂ (ml./min./kg.)
16-18	M	9	3.68 SD ± 0.49	57.6 SD ± 4.3
16-17	F	10	2.71 SD ± 0.29	47.2 SD ± 2.6
20-33	M	42	4.11 SD ± 0.29	58.6 SD ± 4.1
20-25	F	44	2.90 SD ± 0.25	48.4 SD ± 3.2

Astrand, et al. (7) in a later study tested 11 females and 12 males for maximal oxygen uptake on a bicycle ergometer. The results are

presented in tabular form in Table III. These subjects were healthy well trained students in physical education.

TABLE III
DIFFERENCES BETWEEN MALE AND FEMALE IN HEART
RATE AND MAXIMAL OXYGEN UPTAKE

AGE	SEX	NUMBER	MVO ₂ (l./min.)	MAXIMUM HEART RATE(Beats/min)
19-22	F	11	2.60	194
21-30	M	12	4.05	186

BODY COMPOSITION

Brozek and Keys (8) using an underwater weighing technique compared the fat content of male college students with the fat content of middle aged men. The sample and comparison are presented in Table IV.

TABLE IV
COMPARISON OF FAT CONTENT

	Number	Mean Age	SD	Mean % Fat
Male College Students	133	20.3	± 1.9	10.93
Middle Aged Men	122	49.0	± 2.8	21.3

In another study Brozek and Keys (9) compared the fat content for men of standard weight and different ages. The values were derived from groups of individuals of average height and standard weight. The

height and weight determined from Insurance Tables. These results are presented in Table V.

TABLE V
AVERAGE FAT CONTENT FOR MEN OF STANDARD
WEIGHT, DIFFERING IN AGE (9)

Age, years	20	25	30	35	40	45	50	55
Fat, percent	10.3	13.4	16.2	18.6	20.7	22.5	23.9	25.0

Skerlj, Brozek and Hunt (47) used estimated fat content from specific gravity for three groups of different aged women. Their result for 31 subjects of mean age 24.0 was 18.85 percent fat with a range from 11.5 to 29.4 percent.

Durnin and Rahaman (17) in using the underwater weighing method found that for 60 males, mean age 22.0 ± 3.2 years, the percent body fat was 13.5 ± 5.8 ; and for 45 females mean age 21.7 ± 2.4 years, the percent body fat was 24.2 ± 6.5 .

Young, et al. (54) used underwater weighing for density determinations on 94 young women. The percent body fat was calculated using the formulae of Rathbun-Pace, Behnke, and Brozek-Keys. Their results are presented in Table VI.

Conger (12) compares values for percent body fat found in her study and that of Young, et al. (54). These are presented in Table VII.

TABLE VI
PERCENT BODY FAT OF NORMAL YOUNG WOMEN (N = 94)

	Range	Mean	Std. Deviation
Age (yrs.)	17.2-27.2	20.36	± 1.95
Height (ins.)	59.38-71.25	65.94	± 2.37
Weight (kg.)	44.11-76.20	58.96	± 6.44
Body Fat (%)			
Rathbun-Pace	15.81-38.62	28.69	± 4.86
Behnke	15.62-36.51	27.13	± 4.51
Brozek-Keys	15.21-32.59	24.92	± 3.69

TABLE VII
COMPARISON OF BODY FAT - WOMEN

		Age (yr.)	Height (cm.)	Weight (kg)	% Fat
Young's Study	Mean	20.36		58.96	28.55
	SD	± 1.95		± 6.45	± 4.86
Conger's Study	Mean	19.94	164.37	59.00	24.86
	SD	± 4.83	± 6.19	± 2.49	
	Range	18-22		48-69	21-32

In an unpublished study, Macnab and Conger (28) present some characteristics of test subjects. Specific gravity was predicted using

the linear equation devised by Young et al. (53). The characteristics of this sample of young college women is presented in Table VIII.

TABLE VIII
SOME CHARACTERISTICS OF YOUNG COLLEGE WOMEN

Characteristic	Mean	Std. Deviation	Range
Age (yr.)	19.0	± 1.10	17-23
Height (cm.)	164.3	± 6.30	142-177
Weight (kg.)	59.2	± 8.04	44.8-78.0
Body Fat (%) Rathbun-Pace	25.6	± 3.08	20.0-32.2

Sloan (48) presents a comparative table for percent fat of young men as determined by underwater weighing. This table is partially reproduced in Table IX.

TABLE IX
MEAN BODY FAT IN YOUNG MEN,
PERCENT OF BODY WEIGHT

Year	Authors	Country	N	Age	% Fat
1951	Brozek and Keys	U.S.A.	133	20.3 $\pm$ 1.9	10.9
1957	Riendeau, <u>et al.</u>	U.S.A.	61	17-31	13.0
1962	Howell, <u>et al.</u>	U.S.A.	133	20.9 $\pm$ 2.7	18.7
1965	MacMillan, <u>et al.</u>	Scotland	24	18-22	10.7
1967	Sloan	S. Africa	50	18-26	10.8

The very high figure reported by Howell, et al. employed the formula of Rathbun and Pace which gives higher figures for body fat.

Ljunggren (26) states that the fat content values 20-30% of the body weight in normal women and 10-20% for men of normal body weight appear to be reasonable when compared with the results of the few available direct measurements made on cadavers.

CHAPTER III

METHODS AND PROCEDURES

SAMPLE

Twenty-four healthy male and twenty-four healthy female subjects were examined in the study. All the subjects were randomly selected from the population of first year undergraduate students enrolled in the Faculty of Physical Education, the University of Alberta.

ORDER OF TESTING

The tests for each subject were conducted over a three week period. The testing sequence, other than for the first Mitchell, Sproule and Chapman Test and the body densitometry measures, was arranged by permutations. There were four additional tests, twenty-four subjects in each group, and therefore each subject was tested in a different order, with all possible orders of testing being employed for both the male and female groups. Each subject had an equal chance of being tested in one of the twenty-four possible orders of testing. The permutation of four tests completed four at a time is twenty-four (${}^4P_4 = 24$). All subjects performed the Mitchell, Sproule and Chapman Test as their first test, and the body densitometry was measured at the completion of the other tests. Using the above procedure eliminated any training effect which might have been produced if all the tests had been completed in the same order.

STANDARDIZATION OF TESTS

To aid in standardization of testing procedures, all sub-

jects were requested to refrain from eating, smoking, or taking part in strenuous exercise for a period of one and a half hours prior to testing. An attempt was made to have the test schedule arranged for each individual so that the subject was tested at the same relative time of day for each test.

GAS COLLECTION AND ANALYSIS

A four flap triple-J valve was used to allow the subject to breathe outside air and to expire only into the Douglas bags. A rubber mouthpiece was fitted onto the valve and both were attached to a lightweight headgear which permitted easy attachment to the subject. Expired air was analyzed for oxygen content with a Beckman E-2 oxygen analyzer, and for carbon dioxide with a Godart Capnograph. The volume of expired air was measured with an American Meter Company Gasometer.

HEART RATE

The heart rate was recorded by means of a Sanborn electrocardiograph, using a six beat complex. Disc electrodes were used, with the cups filled with Redux for better conductivity.

CALIBRATION OF INSTRUMENTS

The gas analyzers were carefully calibrated prior to use each day and at regular intervals during the testing procedure. This calibration was done with samples of known oxygen content and known carbon dioxide content. As a further check the sample calibration gases were analyzed independently by the Scholander procedure. (40)

The volume meter was calibrated by evacuating a known quantity of gas from a spirometer. A regression equation was calculated and used

as a correction for volumes obtained with the gasometer.

CALCULATION OF FAT FREE BODY WEIGHT

The fat content of the body was determined using a densitometric method.

Equipment - water tank

- twenty pound weight
- Schaevitz Bytrex Model JP-200 strain gauge
- Sargent Model SR recorder
- chair attached to strain gauge and suspended in tank
- Collins spirometer

Procedure - subjects wore nylon bathing suits and were not allowed to wear bathing caps

- subject was weighed on land
- subject then entered tank, sat submerged to neck level in the chair, and vital capacity was measured
- subject removed all air bubbles from body by rubbing
- after maximal inspiration, the subject bent forward into the water until the top of his/her head was below the surface of the water. Subject remained in a relaxed motionless state until tapped with a pole. This procedure was repeated three times and the lowest reading recorded.
- water temperature and density were recorded
- when the underwater weight had been determined, the body density was calculated (see Appendix B)
- the calculation of percent body fat was done using the

- formula of Keys and Brozek (25) where:

$$\% \text{ Fat} = \frac{4.570}{\text{Body Density}} - 4.142$$

PROGRESSIVE STEP TEST

This test was designed with a variable height bench starting at ten centimeters with increments of five centimeter steps up to fifty centimeters. The subjects carried out a twelve minute step test at three 4 minute workloads with each level designed to produce heart rate responses in the ranges 115-130, 135-155, and 160-180. The stepping rate was twenty-eight per minute with frequency established by means of an electric metronome with visual stimulator. Heart rate was plotted against workload and the workload necessary to produce a heart rate of 170 was determined. This was recorded as total height stepped in one minute at a heart rate of 170, and then converted to KGM by multiplying by body weight.

MITCHELL, SPROULE AND CHAPMAN TEST

Mitchell, Sproule and Chapman (33) describe a maximal oxygen uptake test performed on a motor driven treadmill. This test was modified to reduce testing time. The following procedures were used:

- 10 minute warm-up at 3 mph and a 10% grade
- 10 minute rest

Male Subjects

- 2½ minute run at 6 mph and a 7½% grade; expired air was collected during the last minute

- 10 minute rest, expired air was analyzed at this time
- load increased by raising grade $2\frac{1}{2}\%$, speed remained constant at 6 mph; $2\frac{1}{2}$ minute run with expired air collected during last minute
- 10 minute rest
- above procedure repeated raising grade $2\frac{1}{2}\%$ each time until oxygen consumption on two consecutive runs levelled off or declined; the criterion for this decision was an increase of less than 54 ml.(33).

Female Subjects

- as outlined above for male subjects except that initial grade was 0%.

MODIFIED ASTRAND BICYCLE ERGOMETER MVO_2 TEST

Astrand (4) describes a maximal oxygen uptake test performed on a bicycle ergometer. This test was modified so that the subject reached the criterion for maximal oxygen uptake in a single experimental period. The following procedures were used:

- pedal frequency, 50 complete turns per minute, with frequency established by means of an electric metronome with visual stimulator.

Male Subjects

- 4 minute ride at a $2\frac{1}{2}$ kg.load for a warm-up
- 5 minute rest
- 4 minute ride at a $3\frac{1}{2}$ kg.load with expired air collected during the last minute

- 5 minute rest, expired air analyzed during this period
- load increased by $\frac{1}{2}$ kg. and ride repeated as above. This procedure was continued until oxygen uptake levelled off or declined between two successive rides. The criterion for levelling off was an increase in oxygen uptake of 80 ml. or less (3).

Female Subjects

- as for male subjects except that initial load was $1\frac{1}{2}$ kg.

In the Mitchell, Sproule and Chapman, and the Modified Astrand MVO₂ tests, if the subject was unable to complete the full minute during which expired air was being collected, partial bags were used and the values obtained extended to a full minute.

MODIFIED SJOSTRAND PWC₁₇₀

A test of this type was described by Sjostrand (45). This test has been modified by others and was administered as follows:

- pedal frequency 60 complete turns per minute, frequency was established by means of an electric metronome with a visual stimulator.

Male Subjects

- a twelve minute ride consisting of 3 four minute workloads of increasing difficulty. The load level of the first workload determined on a pilot study was constant at 3.5 kg. for all subjects. Second and third workload levels were adjusted depending on heart rate responses at minutes 3 and 7 of the test.

These workloads were adjusted so as to elicit heart rate responses in the ranges 115-130, 135-155, and 160-180 for each of the work levels respectively.

- heart rate was plotted against workload and the workload necessary to produce a heart rate of 170 was determined.

Female Subjects

- test was the same as for males except that the initial workload level was 2.5 kg.

STATISTICAL PROCEDURES

Validity and Reliability of Tests

The Mitchell, Sproule and Chapman Test is recognized, by authorities in the field of exercise physiology, as accurately measuring human physical working capacity. This test was accepted as the criterion measure. Estimates of the validity of the Sjostrand, Progressive Step, and Astrand Tests were then examined.

The reliability of the tests was estimated by the test-retest method for all the tests except the Astrand Bicycle Test and the body densitometry measures.

The Pearson product-moment correlation was used in analyzing the validity and reliability (19).

Testing for Significant Differences

The comparison between male and female for the variables: age, height, weight, MVO_2 as measured by the Mitchell, Sproule and Chapman and the Astrand Tests, and PWC_{170} as measured by the Sjostrand and Progressive Step Tests was done by analysis of variance using the

one-way analysis of variance model described by Winer (52). The .05 level of significance was used in testing for significant differences.

CHAPTER IV

RESULTS AND DISCUSSION

CHARACTERISTICS OF TEST SUBJECTS

Twenty-four healthy male and twenty-four healthy female subjects randomly selected from the population of first year undergraduate students enrolled in the Faculty of Physical Education, the University of Alberta, participated in the study. Some of the characteristics of these subjects are given in Table X.

TABLE X
CHARACTERISTICS OF TEST SUBJECTS

	Mean	Std. Deviation	Range
Females			
Age (yrs)	18.67	± 0.63	17.92-20.42
Height (ins)	65.28	± 2.10	60.5 -68.5
Weight (kg)	59.24	± 5.87	48.65-68.27
Fat (%)	24.03	± 4.49	18.30-33.45
Fat Free Wt (kg)	48.34	± 6.33	36.04-59.31
Males			
Age (yrs)	19.97	± 1.16	18.33-22.42
Height (ins)	70.59	± 2.39	65.5 -75.0
Weight (kg)	76.10	± 8.80	59.42-92.53
Fat (%)	12.96	± 4.53	5.25-21.76
Fat Free Wt (kg)	66.11	± 8.50	49.29-80.42

The characteristics of the female subjects in this study are quite similar to those of the subjects used by Young, et al. (54). Durnin (17), MacMillan (27), Sloan (48), Conger (12), and Macnab and Conger (28). In the other studies the mean age has been around twenty,

the mean weight around fifty-nine kilograms, and the mean fat percent around twenty-five percent.

The percent of fat for the male subjects is slightly higher than that obtained by Brozek and Keys (8, 9), who obtained 10.93 and 10.3 percent for men in the same age range as those in this study. The value obtained here of 12.96 ± 4.53 was quite similar to that of 13.5 ± 5.8 obtained by Durnin and Rahaman (17).

The slight differences in percent fat in these subjects compared to others in the literature may be due to differences in the population sampled and the formula used in the calculation of the percent of body fat.

RELIABILITY OF TESTS

Test-retest reliability coefficients of some of the tests used are presented in Table XI. No figures are available for the Astrand and body composition where only a single measurement was obtained.

TABLE XI
TEST RELIABILITY

Test	Male	Female
Mitchell, Sproule and Chapman	.88	.83
Modified Sjostrand	.91	.75
Progressive Step	.75	.86

In all cases the reliability coefficients were substantially above the level required at the .01 level of significance ($r = .505$) to indicate significant difference from zero. The above indicates that

the administration of the tests which were repeated was reliable and in the light of this the results of tests where only one measure was taken (the Astrand and body densitometry), were also assumed to be reliable.

VALIDITY OF TESTS

The validity coefficients for the tests are given in Table XII. For these coefficients, the raw scores, i.e. l./min. for the Mitchell, Sproule and Chapman, and the Astrand Tests; KPM for the Sjostrand Test; and KGM for the Progressive Step Test; were used in the calculations. In Table XII, the initial Mitchell, Sproule and Chapman Test was used as a standard, with the other tests being validated against this test.

TABLE XII

VALIDITY OF TESTS

	MSC1		MSC2		ASTRAND		SJOSTRAND 1		Step 1	
			M	F	M	F	M	F	M	F
MSC1			.88	.83	.80	.87	.53	.55	.27**	.35**
MSC2			-		.87	.85	.54	.66	.50*	.48*
ASTRAND					-		.56	.62	.53	.45*
SJOSTRAND 1							-		.64	.72

** = not significant
 * = significant at .05 level
 - = all others significant at .01 level

The Astrand Maximal Test correlates very well ($r = .80$ for males and $r = .87$ for females). Thus the Astrand is a valid test of work capacity when the Mitchell, Sproule and Chapman Test is used as a standard. The correlation of the first Sjostrand Test with the Mitchell, Sproule and Chapman Test results in considerably lower

coefficients ($r = .53$ and $.55$ for males and females respectively). These correlations are still significantly different from zero at the .01 level of significance and indicate that the Sjostrand is a valid test of work capacity when the Mitchell, Sproule and Chapman Test is used as a standard. The nonsignificant correlations ($r = .27$ and $.35$ for males and females respectively) between the Progressive Step Test and the Mitchell, Sproule and Chapman Test would seem to indicate that the Step test is not a valid indicator of work capacity as represented by scores on a Mitchell, Sproule and Chapman Test. This does not mean that the Progressive Step Test may not be a valid indicator of work capacity, but just that it is not valid when correlated against a Mitchell, Sproule and Chapman Test.

It is of interest to speculate on the results just cited. One can observe the gradual decrease in relationship (as expressed by the correlation coefficient) as each test becomes further removed from the criterion test (Mitchell, Sproule and Chapman). In viewing the male results, for example, it is possible to observe a fall in coefficients from .88 when the Mitchell, Sproule and Chapman is compared with itself, to .80 when compared with another maximal oxygen uptake test (the Astrand), to .53 (the Sjostrand), and finally to .26 (the Step Test). In spite of this, however, the Sjostrand and the Step Test correlate with each other reasonably well ($r = .64$).

RESULTS OF TESTS

The mean scores of all test results are given in Table XIII. In this table the mean scores and standard deviations are given

TABLE XIII
MEAN SCORES OF TEST RESULTS

TEST	TEST 1		TEST 2		MEAN OF TESTS 1 & 2	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
MITCHELL, SPROULE, CHAPMAN						
	3.91	2.31	3.94	2.33	3.92	2.32
	±.55	±.44	±.65	±.41	±.58	±.41
ml./min./kg.	51.42	39.00	51.69	39.13	51.55	39.06
	±5.32	±6.02	±5.46	±4.87	±5.06	±5.03
ml./min./kg. Fat Free	59.26	47.94	59.61	48.02	59.43	47.98
	±5.93	±7.14	±6.40	±4.87	±5.77	±5.48
ASTRAND						
	3.52	2.12				
	±.61	±.41				
ml./min./kg.	46.31	35.68				
	±6.15	±5.59				
ml./min./kg. Fat Free	53.32	43.83				
	±6.45	±6.50				
PROGRESSIVE STEP						
	887.03	488.85	856.87	487.70	871.95	488.28
	±186.02	±88.55	±190.91	±115.73	±180.08	±109.81
kgm./kg.	11.64	8.24	11.25	8.22	11.45	8.23
	±1.89	±1.54	±2.18	±1.72	±1.90	±1.57
kgm./kg. Fat Free	13.44	10.11	13.00	10.09	13.22	10.10
	±2.28	±1.73	±2.62	±1.67	±2.31	±1.81
SJOSTRAND						
	1366.77	765.13	1323.45	773.50	1345.11	769.32
	±300.07	±167.21	±251.70	±171.37	±269.43	±158.19
kpm/kg.	17.98	12.91	17.42	13.03	17.70	12.97
	±3.44	±2.51	±2.89	±2.40	±3.06	±2.26
kpm./kg. Fat Free	20.74	15.84	20.08	15.98	20.41	15.91
	±4.04	±2.84	±3.30	±2.67	±3.56	±2.50

for each of the tests of maximal oxygen uptake and physical work capacity 170. In the discussion which follows only the results for the mean of tests 1 and 2 for the Mitchell, Sproule and Chapman, the Modified Sjostrand, and the Progressive Step Test are used, along with the results of the single Astrand Bicycle Test.

MAXIMAL OXYGEN CONSUMPTION

For both male and female results there were significant differences between the results for the Mitchell, Sproule and Chapman and the Astrand Tests. (See Table XIV.) These results agree with the findings of Glassford, et al. (21) who found that higher MVO's were obtained with a treadmill test than were obtained with a bicycle test. Astrand and Saltine (6) also found this to be the case in their study of seven adult subjects where a maximal oxygen uptake of 4.69 l./min. and 4.47 l./min. was found on treadmill and bicycle tests respectively. The difference between the two was significant at the .05 level of significance.

TABLE XIV

RESULTS OF ANALYSES OF VARIANCE: TEST VERSUS TEST

TEST A	TEST B	F RATIO	PROBABILITY
<u>Males:</u>			
MSC	Astrand	39.647	Greater than .01
Sjostrand	Step	19.630	Greater than .01
<u>Females:</u>			
MSC	Astrand	27.942	Greater than .01
Sjostrand	Step	49.104	Greater than .01

In comparing the results of this study with those of Astrand (4) it was found that results for subjects from a similar age group were somewhat higher. For males an MVO_2 of $4.11 \pm .29$ litres per minute was found and for females $2.9 \pm .25$ whereas this study found for MVO_2 measured on a bicycle ergometer the results for males were $3.52 \pm .61$ and for females $2.12 \pm .41$.

In this study the mean MVO_2 measured in millilitres per kilogram per minute on the treadmill test was 51.55 ± 5.06 and 39.06 ± 5.03 for males and females respectively. On the bicycle test the mean MVO_2 measured in ml./kg./min. was 46.31 ± 6.15 and 35.68 ± 5.59 for males and females respectively.

Cumming (14) presents comparative values for MVO_2 measured in ml./kg./min. Some of these values are presented in Table XV.

The males in this study obtained comparable results to those of average caucasians in Stockholm and Boston, but lower results than those obtained by Physical Education students in Stockholm. This would seem to indicate that Physical Education students in Stockholm have a higher fitness level than their counterparts in Canada when MVO_2 is used as a standard. Similarly with the females; those in this study obtained values comparable to California "Co-Eds", Stockholm housewives, and Oslo office workers: but much lower than those obtained by Stockholm Physical Education students.

The results of Darwick (15) for a group of 28 young college women 18.2 ± 1.2 yrs. showed a mean MVO_2 of 2.19 ± 3.6 liters per minute. These results obtained on a treadmill test are similar to those for the female MSC of $2.32 \pm .41$ liters per minute.

TABLE XV

MVO₂ OF MALES AND FEMALES 20-40 YEARS OF AGE: MEAN VALUES

SUBJECTS	REFERENCE	MVO ₂
<u>Males:</u>		
Average Caucasian Males:		
Stockholm	2	52
Boston	39	53
Dallas	33	45
Norway	1	44
Winnipeg		44
<u>Athletes:</u>		
Swedish Physical Education Students	4	59
Swedish Cross Country Skiers	5	80
Winnipeg Water-polo Players	22	53
Winnipeg Track Men		72
<u>Females:</u>		
California "Co-Eds"	31	38
Stockholm Housewives	2	40
Oslo Office Workers	1	36
Stockholm Physical Education Students	4	48

PHYSICAL WORK CAPACITY 170

The results of the Sjostrand Test are significantly higher than the results of the Progressive Step Test at the .01 level of significance (see Table XIII). This was determined through the use of a one-way analysis of variance comparing the Sjostrand measured in KPM against the Step measured in KGM for both the males and females. Falls and Buck (18) found a relatively low correlation of .490 between PWC₁₈₀ found on a bicycle test and PWC₁₈₀ found on a step test conducted on 26 graduate Physical Education students. The differences

might be explained in that in stepping approximately one fifth to one third of the work occurs in descent (Shephard (42), Nagle (35), and Passmore and Durnin (36)), and this work is not included in the computation of the work done in the step test, only the positive work of stepping up is included. It is thus probable that a person would obtain a higher score on the Sjostrand than he/she would obtain on the step test.

The mean PWC_{170} for males on the Sjostrand Test was 1345 KPM and for women 769 KPM. Cumming (14) presents comparative tables for men and women for PWC_{170} obtained on submaximal bicycle tests. These comparisons are for various types of subjects in the age range 18-40 years of age. The reported PWC_{170} 's for males range from 965 KPM for Winnipeg medical students to 1551 KPM for Swedish middle distance runners. The PWC_{170} for 'average' men was about 1075. The PWC_{170} for the males studied here is above this average and this would appear reasonable as these were physical education students. Similarly for the females, in this study the mean PWC_{170} on the Sjostrand Test was 769 KPM. This is somewhat less than nurses and medical students in Stockholm who had KPM's of 840 and 835 respectively, while much higher than Winnipeg nurses who had an average KPM of 515. The higher PWC_{170} 's obtained by Swedish women might be explained by the fact that bicycle riding is not as popular in Canada as in Sweden. The superiority of Canadian physical education students over Canadian Nurses is to be expected because of the greater amount of physical activity in which the students partake. Howell and Macnab (23) in the Canadian Association for Health, Physical Education, and Recreation (CAHPER) Work Capacity Study found for 17 year old students from the general school

population of Canada, PWC_{170} values of 873.8 ± 224.5 and 476.7 ± 147.3 respectively for male and female students respectively. In the same study $PWC_{170}/kg.$ of 13.34 ± 2.79 and 8.51 ± 2.23 were obtained by the male and female students respectively. Although these results are for 17 year olds, they are substantially below those obtained in this study for 20 year old males and 18.7 year old females, indicating a general higher work capacity for physical education students compared to the general student population.

COMPARISON OF MALE AND FEMALE

The comparison between male and female was done by means of a one-way analysis of variance as described by Winer. (52) The critical F-ratio at the .01 level of significant is 7.23. The results of the analyses of variance are presented in Table XVI.

The main hypothesis in this study asserted that no significant differences existed between male and female for maximal oxygen uptake and physical work capacity 170 when the scores were expressed in terms of fat free body weight. The alternate hypothesis asserted that significant differences do exist for the above. As seen in Table XVI, significant differences at the .01 level of significance, were found in all four tests between male and female, and thus the alternate hypothesis that significant differences do exist between male and female for maximal oxygen uptake and physical work capacity 170 when the scores are expressed in terms of fat free body weight was accepted. In looking at Table XVI, it can be seen that for all four tests as weight considerations are brought into effect the size of the F-ratio decreases and it decreases even further when fat free

weight considerations are brought into effect. This trend would seem to indicate that the females are approaching closer to the males but even when fat free weight is considered they do not reach the same level as the males.

TABLE XVI

RESULTS OF ANALYSES OF VARIANCE: MALE VERSUS FEMALE

VARIABLE or TEST	F-RATIO	PROBABILITY
Age	60.97	*
Height	67.52	*
Weight	72.41	*
Fat Free Weight	23.03	*
Fat Content	67.04	*
MITCHELL, SPROULE AND CHAPMAN		
l./min.	121.45	*
ml./min./kg.	73.56	*
ml./min./kg. fat free	49.73	*
ASTRAND		
l./min.	87.23	*
ml./min./kg.	39.28	*
ml./min./kg. fat free	25.81	*
SJOSTRAND		
kpm.	81.51	*
kpm./kg.	36.99	*
kpm./kg. fat free	25.71	*
PROGRESSIVE STEP		
kgm.	79.41	*
kgm./kg.	40.89	*
kgm./kg. fat free	27.11	*

* Probability greater than .01 that difference is significant

This study would thus seem to indicate that there are basic differences in work capacity as measured by maximal oxygen uptake or physical work capacity 170 between male and female and that this should be considered in training and choice of events for women. The outstanding feats and type of training carried out by some of the present top women athletes in the world would indicate that there is still much room for study of physiologic differences between male and female.

Various investigators have studied physiological differences between male and female. One of the differences found is that of the hemoglobin content of the blood. Sjostrand (46) found that in adult women, the total quantity of hemoglobin is about 30% the hemoglobin value of men. He found that hemoglobin in adult males accounted for 1.16% of body weight, while in females the hemoglobin accounted for only 0.86% of body weight. Von Döbeln (16) found that for 35 male and 35 female subjects the average hemoglobin content per 100 ml. of blood was $14.95 \pm .17$ g. for the males, and $13.47 \pm .12$ g. for the females. The value for the females was about 10% less than for the males. Astrand, et al. (7) in 11 female and 12 male college physical education students found an average hemoglobin content per 100 ml. of blood, obtained during maximal work, of 15.6 g. for the males, and 13.7 for the females. In an earlier study, Astrand (4) found that in the case of female subjects the relative hemoglobin is 12% lower than for males after about 16 years of age. In this same study, a very high correlation (0.97) was obtained between total hemoglobin and maximal oxygen uptake. In view of the above, the hemoglobin content of the blood may be one of the factors which could be used to explain the differences in work capacity found between male and female in this

study

Another factor which should be considered is cardiac output. Astrand, et al. (7) in their study of 23 physical education students found cardiac output per litre of oxygen uptake during maximal exercise to be 7.1 litres for the males and 5.9 litres for the females. The results were statistically different at the .001 level of significance.

In the same study, maximum pulmonary ventilation for the same subjects was found to be 97 l./min. for the females and 144 l./min. for the males.

Astrand (4) found that the capacity of the lungs of female subjects was about 26% lower than of male subjects. The females had 25.8%, 25.7% and 25.7% lower total lung capacity, vital capacity and residual capacity respectively than the males.

It thus seems probable that a combination of factors including the above mentioned of hemoglobin content, cardiac output, pulmonary ventilation, and lung capacity; perhaps along with other factors; account for the differences found between male and female in physical work capacity.

The subsidiary hypotheses in this study asserted that there were no significant differences between male and female for the variables: age, height, body weight, body composition, maximal oxygen uptake; and physical work capacity 170. The alternate hypotheses asserted that there were significant differences between male and female on the above variables. As seen in Table XVI, significant differences do exist between male and female for all the above mentioned variables. These differences are all significant at the .01 level of significance. These findings, with the exception of age

were expected and confirm the findings of many other investigators who have studied the differences between male and female. This investigator did not expect to find the significant difference in age that was found for the group under study. There is a difference of almost one and a half years between the males and females. This would indicate that the females entering the Faculty of Physical Education, the University of Alberta, do so at a younger age than do the males.

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

It was the purpose of this study to investigate the relationship between male and female for maximal oxygen uptake and physical work capacity $\dot{V}O_2$ when scores are expressed in terms of fat free weight. The subsidiary problem was to investigate the relationship between male and female for the variables: age, height, body weight, body composition maximal oxygen uptake, and physical work capacity $\dot{V}O_2$.

Forty-eight subjects, twenty-four male and twenty-four female, enrolled in the Faculty of Physical Education, the University of Alberta participated in the study. All subjects were tested for: a) maximal oxygen uptake by means of the Mitchell, Sproule and Chapman and the Astrand Tests, b) physical work capacity $\dot{V}O_2$ by means of the Sjostrand and Progressive Step Tests, and c) body density by the hydrostatic weighing technique. Test-retest reliability procedures were carried out on the Mitchell, Sproule and Chapman, Sjostrand, and Progressive Step Tests. All determinations were completed on individual subjects within a three week period with at least two days between maximal tests. Body fat was calculated from the body density measurement, by the formula derived by Keys and Brozek (25). Residual volumes were estimated as twenty-five percent of vital capacity as described by Christie (11).

The test data were analyzed by the one-way analysis of variance procedure as described by Winer (52) to determine relation-

ships between male and female. The reliability and validity procedures were carried out using the Pearson product-moment correlation as described by Ferguson (19).

CONCLUSIONS

Within the limitations of this study, the following conclusions were made.

1. There were significant differences at the .01 level of significance between male and female for the variables: age, height, body weight, body composition, maximal oxygen uptake, and physical work capacity 170, even when scores were expressed in terms of fat free weight.
2. There was a significant correlation at the .05 level of significance between body weight and: the Mitchell, Sproule and Chapman; the Astrand; and the Sjostrand Tests. There was no significant correlation between weight and the Step Test.
3. For all tests, there was a trend for the female results to approach closer to the male results as body weight and fat free body weight was considered. This trend would seem to indicate that the females are approaching closer to the males but even when fat free weight is considered there are still significant differences between male and female in maximal oxygen uptake and physical work capacity 170.

RECOMMENDATIONS

That a study of male and female athletes of world class calibre be carried out to see if the differences between male and female found in this study exist between athletes.

To attempt to discover physiological reasons for the differences found between male and female students in this study.

REFERENCES

1. Andersen, K. L. "Physical Fitness Studies of Healthy Men and Women in Norway," in International Research in Sport and Physical Education, edited by E. Jokl, and F. Simon. Springfield: Charles C. Thomas, 1964, p. 489.
2. Astrand, I. "Aerobic Work Capacity in Men and Women with Special Reference to Age," Acta Physiologica Scandinavica, 49 (Supplement 169):1-92, 1960.
3. _____. "The Physical Work Capacity of Workers 50-64 Years Old," Acta Physiologica Scandinavica, 42:73-86, 1960.
4. Astrand, P.-O. Experimental Studies of Physical Working Capacity in Relation to Sex and Age, Copenhagen: Ejnar Munksgaard, 1952.
5. _____. "Human Physical Fitness with Special Reference to Sex and Age," in International Research in Sport and Physical Education, edited by E. Jokl and E. Simon. Springfield: Charles C. Thomas 1964, p. 517.
6. _____, and B. Saltin. "Maximal Oxygen Uptake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, 16:977-81, 1951.
7. _____, T. E. Cuddy, B. Saltin, and J. Stenberg. "Cardiac Output During Submaximal and Maximal Work," Journal of Applied Physiology, 19:268-276, 1964.
8. Brozek, J., and A. Keys. "The Evaluation of Leanness-Fatness in Man: Norms and Interrelationships," British Journal of Nutrition, 5:194-206, 1951.
9. _____. "Relative Body Weight, Age and Fatness," Geriatrics, 8:70-75, 1953.
10. Buskirk, E. T., and H. L. Taylor. "Relationships Between Maximal Oxygen Uptake and Components of Body Composition," Federation Proceedings, 12:21, 1954.
11. Christie. In Clinical Spirometry. Warren E. Collins, Inc., 1961, p. 18.
12. Conger, P. R. "Physical Performance and Body Form As Related to Physical Activity of College Women," Unpublished Master's Thesis, Michigan State University, East Lansing, 1964
13. Coyne, L. L. "The Relationship of Maximal Oxygen Intake to Body Composition and Total Weight in Active Male," Unpublished Master's Thesis, University of Alberta, Edmonton, 1963.

14. Cumming, G. R. "Current Levels of Fitness," Canadian Medical Journal, 96:868-876, 1967.
15. Darwick, D. "Maximal Work Capacity as Related to Strength, Body Composition and Physical Activity in Young Women," Unpublished Master's Thesis, Michigan State University, East Lansing, 1964.
16. von Döbeln, W. "Maximal Oxygen Intake, Body Size, and Total Hemoglobin in Normal Man," Acta Physiologica Scandinavica, 38:193-199, 1956.
17. Durnin, J. V. G. A., and Rahaman. "Assessment of Fat by Skinfold Thickness," British Journal of Nutrition, 21:681-689, 1961.
18. Falls, H. B., and C. R. Buck. "Investigation of a Modified Step-test Version of Sjöstrand's PWC₁₈₀," Paper presented at meeting of American College of Sports Medicine, Las Vegas, 1967.
19. Ferguson, G. A. Statistical Analysis in Psychology and Education. Second Edition. New York: McGraw-Hill Book Company, 1966.
20. Glassford, R. G. "A Comparison of Maximal Oxygen Consumption Values as Determined by Predicted and Actual Techniques," Unpublished Master's Thesis, University of Alberta, Edmonton, 1964.
21. _____, G. H. Y. Baycroft, A. W. Sedgwick, and R. B. J. Macnab. "Comparison of Maximal Oxygen Uptake Values Determined by Predicted and Actual Methods," Journal of Applied Physiology, 20:509-513, 1965.
22. Goodwin, A. B., and G. R. Cumming. "Radio Telemetry of the Electrocardiogram, Fitness Tests, and Oxygen Uptake of Water Polo Players," Canadian Medical Association Journal, 95:402, 1966.
23. Howell, M. L., and R. B. J. Macnab. The Physical Work Capacity of Canadian Children. Toronto: The Canadian Association for Health, Physical Education and Recreation, 1968.
24. _____, J. Moncrieff and W. R. Morford. "Relationship Between Human Buoyancy Measures, Specific Gravity, and Estimated Body Fat in Adult Males," Research Quarterly, 33:400-404, 1962.
25. Keys, A., and J. Brozek. "Body Fat in Adult Man," Physiological Reviews, 33:245-325, 1953.
26. Ljunggren, H. "Sex Difference in Body Composition," in Brozek, J. ed. Human Body Composition. Oxford: Pergamon Press, 1965. Pp. 129-238.

27. MacMillan, M. G., C. M. Reid, D. Shirling, R. Passmore, "Body Composition, Resting Oxygen Consumption, and Urinary Creatinine in Edinburgh Students," Lancet, 1:728-29, 1965.
28. Macnab, R. B. J., and P. R. Conger. "Observations on the Use of the Astrand-Ryhming Nomogram in University Women," University of Alberta, Edmonton, 1965. (Submitted for Publication).
29. Mahadeva, K., R. Passmore, and B. Woolf. "Individual Variations in the Metabolic Cost of Standardized Exercises: the Effects of Food, Age, Sex and Race," Journal of Physiology, 121:225-231, 1953.
30. Metheny, E., L. Brouha, R. E. Johnson, and W. H. Forbes. "Some Physiologic Responses of Men and Women to Moderate and Strenuous Exercise: A Comparative Study," American Journal of Physiology, 137:318-326, 1942.
31. Michael, E. D. Jr., and S. M. Horvath. "Physical Work Capacity of College Women," Journal of Applied Physiology, 20:263, 1965.
32. Miller, A. T. and C. S. Blythe. "Estimation of Lean Body Mass and Body Fat from Basal Oxygen Consumption and Creatine Excretion," Journal of Applied Physiology, 5:73-78, 1952.
33. Mitchell, J. H., B. J. Sproule, and C. B. Chapman. "The Physiological Meaning of the Maximal Oxygen Intake Test," Journal of Clinical Investigation, 37:538-546, 1958.
34. Nagle, F., and B. Balke. "The Gradational Step Test for Assessing Cardiorespiratory Capacity: An Experimental Evaluation of Treadmill and Step Test Procedures," Federal Aviation Agency Report AM 64-3, Civil Aeromedical Research Institute, Oklahoma City, Oklahoma, 1964.
35. _____, B. Balke, and J. Naughton. "Gradational Step Tests for Assessing Working Capacity," Journal of Applied Physiology, 20:745-748, 1965.
36. Passmore, R., and J. V. G. A. Durnin. "Human Energy Expenditure," Physiological Reviews, 35:801-840, 1955.
37. Rasch, P. J., and W. R. Pierson. "The Relation of Body Surface Area, Mass and Indices to Energy Expenditure," revue canadienne de biology, 21:1-6, 1962.
38. Riendeu, R. P., B. E. Welch, C. E. Crisp, L. V. Crowley, P. E. Griffin and J. E. Brockett. "The Relationships of Body Fat to Motor Fitness Test Scores," United States Army Medical Nutrition Laboratory Report, 209:1-8, 1957.
39. Robinson, S. "Experimental Studies of Physical Fitness in Relation to Age," Arbeitsphysiologie, 10:251-323, 1938.

40. Scholander, P. F. "Analyzer for Accurate Estimation of Respiratory Gases in One-Half Cubic Centimeter Sample," Journal of Biological Chemistry, 167:235-250, 1947.
41. Seltzer, C. C. "Body Build and Oxygen Metabolism at Rest and During Exercise," American Journal of Physiology, 129:1-13, 1940.
42. Shephard, R. J. "The Relative Merits of the Step Test, Bicycle Ergometer, and Treadmill in the Assessment of Cardio-Respiratory Fitness." Arbeitsphysiologie, 23:219-230, 1966.
43. _____. "On the Timing of Post-Exercise Pulse Readings," Journal of Sports Medicine and Rehabilitation, 6:23-27, 1966.
44. _____. "Glossary of Specialized Terms and Units," Canadian Medical Association Journal, 96:912-924, 1967.
45. Sjostrand, T. "Changes in the Respiratory Organs of Workmen at an Ore Smelting Works," Acta Medica Scandinavica, Supplement 196:687-699, 1947.
46. _____. "The Total Quantity of Hemoglobin in Man and Its Relation to Age, Sex, Body Weight and Height," Acta Physiologica Scandinavica, 18:324-336, 1949.
47. Skerlj, B., J. Brozek, and E. E. Hunt. "Subcutaneous Fat and Age Changes in Body Build and Body Form in Women," American Journal of Physical Anthropology, 11:577-600, 1953.
48. Sloan, A. W. "Percent Fat in Young Men," Journal of Applied Physiology, 23:311-315, 1967.
49. _____, J. J. Burt, and C. S. Blyth. "Estimation of Body Fat in Young Men," Journal of Applied Physiology, 17:967-970, 1962.
50. Taylor, H. L., E. Buskirk, and A. Henschel. "Maximal Oxygen Consumption as an Objective Measure of Cardio-Respiratory Performance," Journal of Applied Physiology, 8:73-80, 1955.
51. Welch, B. E., R. E. Riendeau, C. E. Crisp, and R. S. Isenstein. "Relationship of Maximal Oxygen Consumption to Various Components of Body Composition," Journal of Applied Physiology, 12:395-398, 1958.
52. Winer, B. J. Statistical Principles in Experimental Design. New York: McGraw-Hill Book Company, 1962.
53. Young, C. M., M. E. Martin, R. Tensuan, and Blondin. "Predicting Specific Gravity and Body Fatness in Young Women," Journal of American Dietetic Association, 40:102-107, 1962.
54. _____, _____, M. Chihan, M. McCarthy, M. J. Manniello, E. H. Harmuth, and J. H. Fryer. "Body Composition of Young Women," Journal of American Dietetic Association, 38:332-340, 1961.

APPENDICES

APPENDIX A
STATISTICAL PROCEDURES AND
SAMPLE CALCULATION SHEETS

Correlation Coefficients. Correlation coefficients between various tests and variables were obtained using the IBM System 360/67 APL programme SCORR. This programme computes the simple correlation coefficients using the Pearson product-moment correlation (11:111).

$$r = \frac{N \sum XY - \sum X \sum Y}{\sqrt{[N \sum X^2 - (\sum X)^2][N \sum Y^2 - (\sum Y)^2]}}$$

where: r = simple correlation coefficient between

X and Y

N = number of cases

X = sum of the X's

Y = sum of the Y's

Analysis of Variance. Two analyses of variance were used. The first was a one-way analysis of variance (30:46-60) which was used to test the significance of the difference between the males and females. This analysis was carried out using the IBM System 360/67 APL programme ANAL. The second was a one-way analysis of variance with repeated measures (30:105-113) which was used to test the significance of the difference between means for different tests for the males and for the females. This analysis was carried out using the IBM System 360/67 APL programme ANALYSIS.

Regression Equations. Regression equations were used to correct for volume of gas measured by the volume meter, and also to solve for PWC_{170} for both the Sjostrand and Progressive Step Tests.

The regression of X on Y was obtained using the following equation (11:121-122):

$$X' = b_{xy} + a_{xy}$$

where: X' = the predicted value of X estimated from
a knowledge of Y

b_{xy} = the slope of the regression line

a_{xy} = the point where the line intercepts the X axis

The regression equation used to correct for volume of gas was obtained using the IBM System 360/67 APL programme COREL. The volume meter was calibrated by evacuating known volumes from a large Tissot Spirometer in the Cardio-pulmonary Laboratory at the University Hospital. There was also a correction of 300 ml. added to this equation to account for the gas used during the analysis for oxygen and carbon dioxide. The equation used for the correction of volume was:

$$X' = .982 X - .325$$

where: X' = corrected volume

X = volume read on meter

PWC_{170} for the Sjostrand Tests was obtained using the Fortran programme PE 253101 and for the Progressive Step Tests using the Fortran programme PE 253103 on the IBM System 360/67 Computer at the University of Alberta. These programmes calculated the necessary regression equations and then solved these equations for a heart rate of 170 beats per minute.

ESTIMATION OF BODY COMPOSITION

MEASUREMENTS:	POUNDS	LITRES	CUBIC INCHES
Wt. in Air	_____		
Vital Capacity (VC)		_____	_____
Residual Volume (RV)		_____	_____
Volume Gastro-Intestinal (VGI)			_____
Wt. in Water (full inspiration)	_____		

CALCULATIONS:

Total Lung Capacity (TLC) = _____ (VC) + _____ (RV) + _____ (VGI)
 = _____ TLC cu. in.

_____ TLC cu. in. x .0362 = _____ TLC lbs.

True Wt. = _____ (Wt. in Water) + _____ (TLC lbs) = _____.

Body Volume = _____ (Wt. in Air) - _____ (True Wt.) = _____.

Body Density = _____ (Wt. in Air) / (_____ (Body Vol.) x _____ H₂O density)
 = _____.

% Fat = $\frac{4.570}{\text{Body Density}} - 4.142 = \text{_____}\%$

Lbs. Fat = _____ (% Fat) x _____ (Wt.) = _____ lbs.

Lbs. Fat Free = _____ (Wt.) - _____ (Lbs. Fat) = _____ lbs.

GAS ANALYSIS COMPUTATION

NAME:

DATE:

TEMPERATURE:

BAROMETRIC PRESSURE:

TREADMILL INCLINATION/BICYCLE LOAD:

$$\% O_{2E} = . \quad \times 2.5 = \quad \%$$

$$\% CO_{2E} = \quad \%$$

$$\% N_{2E} = 100 - \quad \% O_{2E} - \quad \% CO_{2E} = \quad \%$$

$$V_{EATPS} = .982 \times \quad - .325 = \quad \text{L/Min.}$$

$$(\text{partial to whole sample ATPS} = \quad \times \quad \text{L.} = \quad \text{L/Min.})$$

$$V_E \text{ STPD} = \quad (\text{factor}) \times \quad \text{L/Min.} = \quad \text{L/Min.}$$

$$V_I \text{ STPD} = \quad V_E \text{ STPD} \times \frac{\quad \%}{79.04} N_{2E} = \quad \text{L/Min.}$$

$$VO_2 = (\quad V_I \text{ STPD} \times .2093) - (\quad V_E \text{ STPD} \times . \quad O_{2E})$$

$$= \quad \text{L/Min. Oxygen Uptake.}$$

APPENDIX B
CORRELATION MATRICES

CORRELATIONS FOR ALL TESTS - MALES

	ASTRAND	MSC		MSC		SJOSTRAND		SJOSTRAND		STEP mean	STEP 1	STEP 2
		mean	1	2	mean	1	2	mean	2			
Body Weight	.60	.72	.65	.74	.51	.48	.52	.61	.53	.63	.53	
Astrand	-	.87	.80	.87	.62	.56	.67	.53	.49	.53	.49	
MSC mean		-	.96	.97	.60	.55	.61	.41	.37	.41	.37	
MSC 1			-	.88	.58	.53	.61	.30	.31	.27	.31	
MSC 2				-	.58	.54	.59	.48	.41	.50	.41	
Sjostrand mean				-	-	.98	.97	.74	.75	.67	.75	
Sjostrand 1					-	-	.91	.73	.76	.64	.76	
Sjostrand 2							-	.72	.71	.67	.71	
Step mean								-	.96	.95	.96	
Step 1									-	-	.83	

In all the above tests the scores used for the calculation of the correlation coefficients were in l./min., kpm, or kgm.

CORRELATIONS FOR ALL TESTS - FEMALES

	ASTRAND	MSC		MSC		SJOSTRAND		SJOSTRAND		STEP mean	STEP 1	STEP 2
		mean	1	2	1	2	mean	1	2			
Body Weight	.59	.69	.60	.72	.53	.44	.55	.52	.39	.47		
Astrand	=	.90	.87	.85	.67	.66	.60	.54	.45	.48		
MSC mean		=	.96	.95	.63	.63	.55	.57	.43	.52		
MSC 1			=	.83	.54	.55	.45	.51	.35	.47		
MSC 2				=	.68	.66	.60	.59	.48	.53		
Sjostrand mean				=		.93	.94	.85	.80	.82		
Sjostrand 1						=	.75	.79	.72	.77		
Sjostrand 2							=	.80	.77	.76		
Step mean								=	.92	.96		
Step 1									=	.82		

In all the above tests the scores used for the calculation of the correlation coefficients were in l./min., kpm, or kgm.

In all the above tests the scores used for the calculation of the correlation coefficients were in l./min., kpm, or kgm.

APPENDIX C

RAW SCORES

RAW SCORES - ASTRAND MAXIMAL OXYGEN UPTAKE TEST - FEMALES

SUBJECT	BICYCLE LOAD KG.	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
01	2.5	17.175	5.5	41.077	1.473
	3.0	17.2	5.3	53.638	1.782
	3.5	17.475	5.1	59.910	1.814
02	2.5	18.55	3.4	70.982	1.503
	3.0	18.45	3.3	66.136	1.502
03	2.5	17.675	3.2	58.094	1.904
	3.0	18.05	2.9	75.442	2.152
	3.5	18.05	2.8	73.959	
04	2.5	17.15	3.5	59.910	2.314
	3.0	17.125	3.6	46.745	1.805
	3.5	17.55	3.2	60.234	2.069
05	2.5	16.425	6.2	38.642	1.570
	3.0	16.95	5.9	54.836	1.908
	3.5	17.475	4.95	68.686	2.107
	4.0	17.675	4.25	71.899	2.157
06	2.5	17.138	3.4	41.995	1.640
	3.0	17.763	3.0	64.437	2.075
	3.5	18.125	2.55	76.227	2.196
07	2.5	17.25	5.1	45.025	1.491
	3.0	17.75	4.4	58.784	1.684
	3.5	18.6	3.7	82.364	1.627
08	2.5	17.875	4.5	52.138	1.397
	3.0	18.175	4.2	67.357	1.599
	3.5	18.225	3.8	69.225	1.677
	4.0	18.375	3.6	77.358	1.769

SUBJECT	BICYCLE LOAD KG.	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
09	2.5	17.025	3.7	61.370	2.435
	3.0	16.863	3.75	45.301	1.884
	3.5	16.875	3.7	50.853	2.114
	4.0	17.275	3.5	65.948	2.443
	4.5	17.5	3.35	79.847	2.762
	5.0	17.625	3.1	84.425	2.843
10	2.5	17.612	5.0	59.611	1.717
	3.0	17.825	4.2	67.999	1.920
11	2.5	17.2	5.4	50.5938	1.667
	3.0	18.125	4.0	82.424	2.058
	3.5	17.875	4.35	71.976	1.958
12	2.5	16.7	4.0	35.409	1.522
	3.0	17.325	3.4	51.305	1.881
	3.5	17.4	3.2	52.403	1.900
13	2.5	16.712	5.6	40.706	1.571
	3.0	17.15	5.3	54.082	1.831
	3.5	17.9	4.6	83.060	2.178
	4.0	18.262	3.8	93.788	2.228
14	2.5	16.725	3.8	34.091	1.473
	3.0	17.187	3.6	52.876	2.003
	3.5	17.125	3.6	53.595	2.073
15	2.5	16.9	3.9	40.677	1.657
	3.0	17.225	3.5	55.536	2.092
	3.5	17.85	3.0	73.105	2.273
	4.0	18.125	2.65	86.404	2.466
	4.5	18.125	2.35	84.023	2.465
16	2.0	18.1	3.6	40.442	1.065
	2.5	18.512	3.2	52.841	1.172

SUBJECT	BICYCLE LOAD KG.	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
17	2.5	16.025	6.3	33.620	1.528
	3.0	15.925	6.8	37.971	1.722
	3.5	16.587	6.1	52.972	2.058
	4.0	17.6	4.3	74.031	2.281
18	2.5	16.525	4.2	38.424	1.717
	3.0	16.6	4.1	46.159	2.030
	3.5	17.462	3.8	70.767	2.397
	4.0	17.937	3.1	90.231	2.682
19	2.5	17.75	3.9	48.103	1.572
	3.0	17.8	2.9	57.926	1.853
	3.5	18.0	2.85	68.384	2.024
20	2.5	18.05	4.0	69.773	1.808
	3.0	18.337	3.7	100.855	2.327
	3.5	18.375	3.4	94.333	2.207
21	2.5	15.95	4.4	31.164	1.602
	3.0	15.95	4.6	39.930	2.032
	3.5	16.2	4.4	50.185	2.422
	4.0	16.45	4.4	60.841	2.743
	4.5	17.325	3.4	79.982	2.933
	4.75	17.225	3.0	73.950	2.888
22	2.5	17.025	5.7	47.673	1.639
	3.0	18.35	4.4	90.247	1.901
	3.5	18.387	3.3	96.874	2.274
23	2.5	17.4	3.3	43.679	1.572
	3.0	17.775	3.0	64.062	2.053
	3.5	17.975	2.8	73.327	2.203
	4.0	17.9	2.7	79.671	2.490
	4.5	17.8	2.5	69.611	2.301
24	2.5	17.988	3.4	52.782	1.493
	3.0	18.05	2.9	57.413	1.655

RAW SCORES - ASTRAND MAXIMAL OXYGEN UPTAKE TEST - MALES

SUBJECT	BICYCLE LOAD KG.	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
25	3.5	16.625	5.9	37.369	1.454
	4.0	15.7	6.8	52.648	2.539
	4.5	16.325	6.5	71.477	2.939
	5.0	15.95	6.9	71.321	3.194
	5.5	16.975	5.75	99.433	3.468
	5.75	16.85	5.1	89.894	3.432
26	3.5	15.95	6.2	49.159	2.293
	4.0	15.937	7.0	55.842	2.496
	4.5	16.35	6.6	73.276	2.970
	5.0	16.862	5.9	90.830	3.261
	5.5	17.287	5.2	107.740	3.489
	5.75	17.4	4.175	102.667	3.457
27	3.5	17.525	4.5	53.364	1.667
	4.0	18.0	4.0	76.263	2.024
	4.5	18.625	3.4	99.405	2.011
	5.0	18.675	3.25	103.127	2.062
28	3.0	18.0	6.25	50.913	1.048
	4.0	17.15	5.0	74.624	2.551
	4.5	16.7	4.4	74.535	3.125
	5.0	17.65	4.8	142.202	4.103
29	3.5	17.175	5.05	68.953	2.358
	4.0	17.65	4.6	104.123	3.060
	4.5	17.5	4.7	105.875	3.284
	5.0	17.65	4.5	129.949	3.686
30	4.0	15.625	4.7	55.346	3.029
	4.5	16.05	4.6	78.692	3.905
	5.0	16.325	4.35	89.978	4.211
	5.5	16.675	4.25	114.213	4.870
	6.0	17.125	3.6	132.015	5.105

SUBJECT	BICYCLE LOAD KG.	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
31	3.5	17.963	4.5	83.422	2.144
	4.0	18.175	4.3	104.962	2.471
	4.5	18.125	4.375	122.371	2.933
	5.0	17.9	3.75	98.52	2.805
32	3.5	16.425	4.2	59.883	2.751
	4.0	17.75	4.0	68.218	2.027
	4.5	18.2	3.4	87.935	2.252
	5.0	17.0	3.4	85.699	3.209
33	3.5	16.125	4.4	51.328	2.525
	4.0	16.588	4.1	70.627	3.118
	4.5	17.138	3.6	85.969	3.311
	5.0	17.5	3.25	102.739	3.581
34	3.5	16.25	4.6	51.760	2.437
	4.0	16.65	4.3	67.686	2.899
	4.5	17.5	3.3	91.658	3.183
	5.0	17.725	2.9	98.513	3.245
35	3.5	15.975	4.4	49.723	2.572
	4.0	16.413	4.4	60.150	2.741
	4.5	16.225	4.575	64.999	3.086
	5.0	16.8	4.2	86.069	3.546
	5.5	16.95	3.7	82.768	3.362
36	3.5	15.938	4.6	28.088	1.434
	4.0	15.9	4.8	49.894	2.544
	4.5	16.225	4.8	66.475	3.116
	5.0	17.538	3.45	111.455	3.773
	5.5	17.5	3.0	119.934	4.260

SUBJECT	BICYCLE LOAD KG.	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
37	3.5	17.275	5.1	69.650	2.285
	4.5	17.287	5.1	87.298	2.850
	5.0	17.4	5.0	99.183	3.181
	5.0	17.5	4.6	101.841	3.186
	5.25	17.462	4.7	109.602	3.451
	5.5	17.362	4.7	103.475	3.390
38	3.5	15.875	4.4	49.557	2.595
	4.0	15.75	4.9	54.598	2.873
	4.5	15.95	4.8	64.551	3.251
	5.0	15.775	5.0	71.389	3.715
	5.5	16.7	4.6	94.725	3.921
	6.0	17.525	3.4	126.281	4.312
39	6.5	17.475	3.0	117.938	4.226
	3.5	16.537	6.1	48.979	1.934
	4.0	16.688	6.1	60.104	2.259
	4.5	16.8	5.8	82.793	3.060
	5.0	16.9	5.8	88.796	3.169
	5.5	17.25	5.0	96.889	3.235
40	3.5	16.05	4.4	49.947	2.505
	4.0	16.3	4.3	62.682	2.962
	4.5	16.725	4.1	77.083	3.269
	5.0	16.9	3.9	88.231	3.593
	5.5	16.95	3.6	93.111	3.807
41	3.5	15.275	5.2	36.512	2.112
	4.0	15.45	5.2	44.997	2.503
	4.5	15.25	5.25	44.635	2.590
	5.0	15.775	5.1	55.694	2.884
	5.5	16.925	3.8	88.990	3.619
	5.75	17.1	3.5	89.875	3.528
42	3.5	16.4	6.2	52.043	2.132
	4.0	16.775	5.8	65.246	2.432
	4.5	17.975	4.0	102.092	2.742
	5.0	18.187	3.9	125.576	3.069

SUBJECT	BICYCLE LOAD KG.	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
43	3.5	16.688	4.1	51.102	2.191
	4.0	16.35	4.3	57.647	2.688
	4.5	16.375	4.35	63.624	2.938
	5.0	16.7	3.9	79.886	3.455
	5.5	17.2	3.45	92.976	3.544
44	3.5	15.775	6.8	51.359	2.428
	4.0	15.9	6.7	58.255	2.677
	4.5	16.037	7.0	71.141	3.089
	5.0	17.087	5.4	90.496	3.205
45	3.5	16.5	6.4	52.433	2.053
	4.0	17.225	5.4	73.518	2.399
	4.5	17.425	4.9	80.074	2.517
46	3.5	16.55	4.15	56.510	2.514
	4.0	16.263	4.4	57.367	2.723
	4.5	16.7	4.2	65.813	2.794
	5.0	17.15	3.8	88.662	3.354
47	3.5	16.7	3.9	65.666	2.840
	4.0	16.8	3.8	85.821	3.626
	4.5	17.05	3.5	93.239	3.719
	5.0	17.375	3.2	111.379	4.068
48	3.5	16.15	4.25	58.714	2.894
	4.0	16.988	3.5	89.952	3.659
	4.5	17.3	3.1	97.432	3.681

RAW SCORES - MITCHELL, SPROULE AND CHAPMAN TEST ONE - FEMALES

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
01	0	17.225	4.75	49.784	1.701
	2½	17.375	4.5	54.056	1.791
	5	17.575	4.5	60.990	1.905
	7½	17.775	4.15	69.080	2.003
	10	17.575	3.1	54.862	1.882
02	0				
	2½	17.687	4.12	61.308	1.855
	5	17.868	3.83	53.162	1.527
03	0	17.375	3.6	51.977	1.846
	2½				
	5	17.7	3.4	67.518	2.156
	7½	17.6	3.4	67.840	2.252
	10	17.65	3.0	66.552	2.238
04	0	16.975	3.0	51.199	2.158
	2½	17.125	3.4	57.149	2.240
	5	17.3	3.0	87.338	2.323
	7½	17.925	3.5	64.995	1.873
05	0	16.963	4.85	50.385	1.885
	2½	17.0	4.9	53.958	1.986
	5	17.275	5.05	62.182	2.048
	7½	17.55	4.8	72.982	2.198
06	0	17.625	3.0	56.166	1.906
	2½	17.8	2.8	63.792	2.058
	5	17.675	3.1	64.865	2.143

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
07	0	17.475	4.8	67.562	2.099
	2½	17.45	4.55	69.410	2.224
	5	17.512	4.6	71.499	2.225
08	0	17.785	4.4	58.126	1.640
	2½	17.588	4.25	60.853	1.893
	5	17.88	4.4	66.870	1.800
09	0	17.45	3.4	67.415	2.366
	2½	17.275	3.6	68.633	2.524
	5	17.375	3.6	76.832	2.728
	7½	17.425	3.4	83.241	2.947
	10	17.65	3.0	92.800	3.120
10	0	16.695	5.38	43.967	1.729
	2½	16.85	5.19	46.503	1.764
	5	16.625	5.29	52.474	2.126
	7½	16.85	5.0	61.145	2.351
	10	17.1	4.81	42.453	1.519
11	0	17.5	4.38	66.956	2.133
	2½	17.35	4.2	68.788	1.937
	5	17.65	4.4	76.085	2.276
	7½	18.75	4.3	81.220	1.321
12	0	16.85	3.4	46.037	1.965
	2½	16.975	3.4	48.873	2.009
	5	16.975	3.425	53.687	2.203
	7½	17.137	3.425	60.615	2.363
	10	17.575	2.8	60.756	2.133

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
13	0	17.894	4.81	60.298	1.555
	2½	17.35	4.71	62.973	2.071
	5	17.575	4.42	81.766	2.516
14	0	16.525	3.6	36.644	1.695
	2½	16.45	3.55	37.961	1.797
	5	16.525	3.75	51.158	2.346
	7½	17.0	3.6	51.398	2.069
15	0	16.287	4.1	37.166	1.782
	2½	15.938	4.35	34.586	1.788
	5	15.825	4.7	36.917	1.927
	7½	17.075	3.8	60.648	2.352
	10	18.138	2.8	86.445	2.419
	12½	17.8	2.1	71.520	2.439
16	0	18.27	3.8	51.401	1.217
	2½	18.52	3.0	64.490	1.419
17	0	16.763	5.05	35.403	1.396
	2½	15.575	5.4	41.104	2.200
	5	15.438	5.6	45.011	2.463
	7½	15.9	5.6	54.739	2.675
18	0	16.35	3.9	54.628	2.605
	2½	16.587	3.9	55.263	2.469
	5	16.7	3.8	56.533	2.560
	7½	17.0	4.0	86.763	3.401
	10	17.1	3.8	75.361	2.091

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
19	0	17.063	3.3	42.246	1.702
	2½	17.41	3.2	53.055	1.916
	5	17.650	3.1	60.493	2.018
	7½	17.75	2.9	68.465	2.224
20	0	18.162	4.0	69.919	1.712
	2½	18.025	3.9	74.091	1.963
	5	18.05	4.0	83.397	2.161
	7½	18.325	3.6	97.357	2.287
	10	18.237	2.8	82.113	2.194
21	0	15.913	4.3	48.921	2.451
	2½	15.458	4.5	42.172	2.420
	5	15.675	4.55	50.732	2.762
	7½	15.645	4.6	48.674	2.665
	10	16.513	4.2	66.219	2.969
22	0	17.775	5.0	59.699	2.050
	2½	18.1	4.3	71.632	1.754
	5	18.525	3.8	82.758	1.691
23	0	17.238	3.4	56.372	2.129
	2½	17.05	3.65	56.818	2.242
	5	17.3	3.6	64.080	2.336
	7½	17.6	3.3	74.624	2.497
	10	17.775	3.1	83.698	2.660
24	0	17.125	3.9	39.492	1.496
	2½	17.2	3.65	41.798	1.571
	5	17.687	3.35	47.764	1.539

RAW SCORES -- MITCHELL, SPROULE AND CHAPMAN TEST ONE -- MALES

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
25	7½	15.85	6.7	63.972	2.980
	10	15.92	6.7	70.410	3.218
	12½	16.237	6.4	84.357	3.584
	15	16.997	5.65	110.289	3.844
	17½	17.47	4.05	115.384	3.821
26	7½	15.975	6.7	62.591	2.817
	10	16.412	6.3	73.514	2.980
	12½	16.485	6.1	84.254	3.384
	15	18.328	5.85	100.866	1.766
27	7½	16.65	5.6	61.042	2.404
	10	16.775	5.2	64.179	2.494
	12½	17.225	4.8	79.379	2.717
	15	17.563	4.6	94.298	2.875
	17½	17.575	3.0	69.607	2.406
28	7½	16.3	5.8	74.858	3.240
	10	16.625	5.6	91.707	3.641
	12½	16.625	5.55	102.675	4.090
	15	16.84	5.25	104.833	3.974
	17½	17.15	3.39	118.012	4.592
29	7½	17.137	5.3	93.447	3.178
	10	17.375	4.9	109.471	3.511
	12½	17.325	4.85	112.370	3.690
	15	17.5	4.8	126.140	3.879
	17½	17.5	3.5	108.940	3.725
30	7½	16.05	4.7	81.001	3.998
	10	16.125	4.8	102.002	4.911
	12½	16.3	4.7	104.447	4.825
	15	16.664	4.7	114.482	4.800

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
31	7½	17.325	5.3	94.178	2.980
	10	17.525	4.85	103.945	3.150
	12½				
	15	17.3	4.6	99.860	3.376
32	7½	16.0	4.4	63.184	3.209
	10	16.4	4.0	74.518	3.486
	12½	16.95	3.8	91.772	3.704
	15	17.287	3.55	106.455	3.912
	17½	17.375	3.0	109.847	4.075
33	7½	16.087	4.4	64.456	3.202
	10	16.1	4.4	71.471	3.539
	12½	16.7	4.3	89.772	3.788
	15	17.2	3.75	106.057	3.976
	17½	17.4	3.4	115.733	3.394
34	7½	16.763	4.3	75.953	3.145
	10	17.45	3.8	103.102	3.509
	12½	18.063	3.0	129.729	3.667
35	7½	16.55	4.72	72.806	3.129
	10	16.587	4.56	85.413	3.665
	12½	16.788	4.4	87.882	3.585
36	7½	15.75	5.0	68.338	3.578
	10	16.025	4.8	79.913	3.948
	12½	16.825	4.0	109.184	4.521
	15	17.437	3.3	133.592	4.744

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
37	7½	16.737	5.35	94.299	3.672
	10	16.95	5.1	97.040	3.582
	12½	17.212	4.8	120.595	4.147
	15	17.525	4.3	130.327	4.139
38	7½	16.0	4.4	75.867	3.853
	10	16.25	4.35	84.448	4.033
	12½	16.7	4.2	101.965	4.329
	15	16.825	4.2	112.928	4.616
	17½	16.775	4.0	109.036	4.584
39	7½	16.162	6.6	72.423	3.107
	10	16.388	6.4	85.398	3.479
	12½	16.708	6.1	85.112	3.178
40	7½	15.625	4.9	58.726	3.183
	10	15.925	4.7	71.724	3.653
	12½	16.625	4.175	87.432	3.804
	15	16.925	3.6	91.419	3.767
41	7½	15.675	4.5	67.744	3.646
	10	15.312	4.6	63.187	3.725
	12½	15.637	4.5	72.100	3.973
	15	17.2	3.8	104.674	4.555
42	7½	16.687	5.8	71.828	2.757
	10	16.667	5.2	84.328	3.431
	12½	16.95	5.2	103.983	3.811
	15	17.375	4.8	112.257	3.630

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
43	7½	16.1	4.55	66.876	3.285
	10	15.975	4.6	72.130	3.648
	12½	16.762	4.1	92.334	3.872
	15	16.937	4.0	101.628	4.064
	17½	17.1	3.8	113.064	4.348
44	7½	17.05	6.6	77.104	2.442
	10	16.025	7.0	76.015	3.313
	12½	17.0	5.6	108.782	3.803
	15				
45	7½	16.325	4.9	58.221	2.642
	10	16.75	4.8	66.88	2.692
	12½	17.43	4.3	84.59	2.795
	15	18.05	3.8	99.74	2.639
46	7½	16.537	4.5	66.739	2.918
	10	17.2	3.8	84.355	3.138
	12½	17.413	3.55	94.712	3.331
	15	17.263	3.35	91.475	3.439
47	7½	16.7	3.85	85.192	3.696
	10	17.038	3.6	81.203	3.228
48	7½	16.4	4.35	77.948	3.574
	10	16.537	4.0	89.606	4.036
	12½	16.875	3.8	102.823	4.247
	15	17.3	3.6	115.548	4.213

RAW SCORES - MITCHELL, SPROULE AND CHAPMAN TEST TWO - FEMALES

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
01	0	17.325	4.65	46.133	1.539
	2½	17.575	4.5	53.364	1.633
	5	17.725	4.35	61.930	1.802
	7½	18.025	4.25	67.729	1.732
02	0	18.08	4.2	59.367	1.484
	2½	18.225	3.8	66.629	1.614
	5	18.375	3.75	73.793	1.658
03	0	17.2	3.1	53.684	2.096
	2½	17.375	3.2	61.546	2.251
	5	17.65	3.1	65.313	2.179
	7½				
04	0	16.825	3.425	46.493	1.996
	2½	16.683	3.575	47.238	2.094
	5	16.9	3.6	54.437	2.260
	7½	17.525	3.3	70.145	2.414
	10	17.888	2.95	83.773	2.576
05	0	17.45	3.7	66.101	2.267
	2½	17.2	3.8	60.781	2.261
	5	17.8	3.2	78.370	2.445
	7½	17.625	3.0	77.910	2.644
06	0	17.425	3.0	54.147	1.975
	2½	17.1	3.2	49.015	1.963
	5	17.488	3.2	64.452	2.265
	7½	17.75	3.1	73.908	2.372

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
07	0	17.475	4.75	67.133	2.095
	2½	17.45	4.675	66.972	2.124
	5	17.425	4.7	73.451	2.351
	7½	17.663	4.6	82.435	2.409
	10	17.875	4.1	85.934	2.394
08	0	17.45	4.2	50.780	1.674
	2½	17.4	4.05	55.093	1.873
	5	17.6	4.3	72.866	2.245
	7½	17.988	4.2	77.543	2.030
09	0	17.15	3.3	55.552	2.775
	2½	16.925	3.6	68.493	2.356
	5	17.05	3.3	64.982	2.626
	7½	17.125	3.65	71.705	2.764
	10	17.5	3.3	84.620	2.938
	12½	17.7	2.7	91.228	3.082
10	0	16.925	5.2	43.216	1.621
	2½	17.125	5.175	50.271	1.734
	5	17.063	5.2	51.223	1.804
	7½	17.4	5.1	61.905	1.933
	10	17.7	4.8	70.272	1.983
11	0	17.675	4.75	66.908	1.918
	2½	17.688	4.5	68.514	1.999
	5	17.725	4.8	76.942	2.147
	7½	17.713	4.8	83.391	2.340
12	0	16.375	3.85	38.333	1.821
	2½	16.7	3.5	42.104	1.866
	5	16.713	3.7	44.417	1.938
	7½	16.962	3.6	52.436	2.136
	10	17.275	3.1	60.390	2.301

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
13	0	16.95	5.5	56.104	2.012
	2½	17.775	5.1	61.360	1.625
	5	17.5	5.2	72.720	2.159
	7½	17.6	4.9	82.653	2.415
	10	18.1	4.0	96.260	2.434
14	0	17.263	3.05	46.520	1.786
	2½	17.388	2.8	54.045	2.025
	5	17.313	2.15	55.818	2.241
	7½	17.625	3.3	64.176	2.127
15	0	15.925	4.2	32.772	1.713
	2½	16.35	3.9	42.684	2.035
	5	16.783	3.7	49.159	2.101
	7½	17.05	3.6	61.485	2.436
	10	17.85	2.9	80.273	2.517
16	0	17.725	4.55	52.172	1.490
	2½	18.025	4.0	59.731	1.567
	5	18.35	3.0	65.823	1.630
17	0	16.325	4.9	45.286	2.054
	2½	16.212	4.9	54.806	2.563
	5	16.512	5.0	54.401	2.324
18	0	16.638	3.45	47.440	2.146
	2½	16.763	3.4	56.341	2.467
	5	16.675	3.95	62.491	2.714
	7½	16.95	3.75	69.482	2.813
	10	17.425	3.75	84.816	2.925
	12½	17.625	2.3	83.876	3.002

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
19	0	17.25	3.1	42.529	1.634
	2½	17.3	3.1	50.965	1.926
	5	17.413	3.2	55.716	2.013
	7½	17.875	2.8	66.888	2.091
20	0	18.15	4.0	69.055	1.686
	2½	18.1	3.9	78.450	2.005
	5	18.3	3.9	88.282	2.032
	7½	18.338	3.8	92.182	2.102
21	0	15.075	4.3	34.920	2.191
	2½	17.469	4.3	36.086	1.172
	5	15.0	4.5	35.362	2.234
	7½	15.713	4.3	50.635	2.769
	10	16.563	3.9	67.581	3.041
	12½	17.375	3.1	88.218	3.249
22	0	17.062	5.8	61.226	2.059
	2½	17.337	5.5	73.712	2.282
	5	17.7	4.4	84.709	2.480
	7½	18.112	3.95	92.624	2.342
23	0	17.275	3.65	52.830	1.936
	2½	17.35	3.5	55.397	1.999
	5	18.238	2.9	79.980	2.116
	7½	18.187	3.1	81.793	2.172
24	0	17.213	3.75	43.120	1.603
	2½	17.55	3.3	50.447	1.720
	5	17.738	3.3	56.003	1.776

RAW SCORES - MITCHELL, SPROULE AND CHAPMAN TEST TWO - MALES

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
25	7½	15.337	7.2	57.292	2.965
	10	15.3	7.5	64.458	3.315
	12½	16.075	6.9	82.818	3.579
	15	16.725	6.8	109.713	3.863
26	7½	16.032	7.2	63.929	2.677
	10	16.045	7.1	69.459	2.991
	12½	16.262	7.0	76.465	3.103
	15	16.95	6.6	95.063	3.132
27	7½	17.062	5.35	87.200	2.554
	10	17.252	5.0	84.443	2.816
	12½	17.65	4.55	92.949	2.744
	15				
28	7½	16.075	7.0	77.169	3.314
	10	16.075	6.6	82.170	3.616
	12½	16.4	6.4	95.359	3.855
	15	16.6	6.1	102.399	3.962
	17½	17.025	5.7	118.987	4.090
	20	17.15	4.7	118.012	4.183
	22½	16.375	4.6	85.381	3.882
29	7½	17.3	5.175	88.469	2.857
	10	17.2	4.9	89.306	3.062
	12½	17.65	4.8	109.041	3.146
	15	17.538	4.9	116.138	3.483
	17½	17.938	4.5	116.776	3.038
30	7½	16.1	4.4	82.621	4.339
	10	16.3	4.4	99.406	4.671
	12½	16.55	4.3	112.241	4.949
	15	16.925	4.1	129.353	5.158
	17½	17.05	4.0	142.834	5.508

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
31	7½	17.55	5.0	93.804	2.776
	10	17.525	4.8	106.227	3.233
	12½	17.812	4.5	113.695	3.140
32	7½	16.125	4.6	66.713	3.247
	10	16.6	4.0	84.267	3.729
	12½	16.85	4.0	93.528	3.843
	15	16.875	3.7	90.548	3.764
33	7½	16.525	4.3	65.264	2.898
	10	16.763	4.2	81.607	3.400
	12½	17.0	3.95	93.011	3.658
	15	17.4	3.7	109.981	3.842
	17½	17.313	3.4	110.544	3.897
34	7½	16.75	4.0	83.099	3.470
	10	17.113	3.7	92.184	3.555
	12½	17.775	3.1	117.329	3.728
	15	18.275	2.1	122.762	3.450
35	7½	16.512	3.95	76.564	3.483
	10	16.837	3.9	84.243	3.497
	12½	16.7	3.95	83.844	3.615
	15	17.438	3.3	108.802	3.864
	17½	17.612	2.175	101.242	3.676
36	7½	16.188	4.5	77.878	3.750
	10	16.625	4.2	94.831	4.116
	12½	17.225	3.6	117.816	4.407
	15	17.325	3.25	131.689	4.882

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
37	7½	16.838	5.9	103.288	3.741
	10	17.138	5.1	119.563	4.130
	12½	17.5	4.6	134.539	4.209
	15	17.575	3.05	106.639	3.672
38	7½	16.525	4.0	85.295	3.856
	10	16.513	3.9	95.581	4.361
	12½	16.5	3.8	102.575	4.723
	15	16.7	4.0	108.747	4.675
39	7½	16.413	6.6	77.121	3.065
	10	16.475	6.35	85.772	3.398
	12½	17.18	5.5	104.327	3.427
40	7½	16.125	4.2	67.910	3.377
	10	15.963	4.6	74.080	3.758
	12½	16.4	4.2	89.001	4.117
	15	16.65	3.8	91.509	4.040
41	7½	16.526	4.25	74.492	3.317
	10	15.525	6.25	59.088	3.066
	12½	15.613	4.9	71.363	3.879
	15	16.288	4.55	85.804	4.009
	17½	17.025	3.7	114.437	4.540
42	7½	17.2	5.9	76.068	2.887
	10	17.025	5.5	96.994	3.386
	12½	17.125	5.2	104.793	3.609
	15	17.45	5.1	114.296	3.496
	17½	17.85	4.3	125.003	3.456

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITRES/MINUTE
43	7½	16.125	4.6	67.999	3.310
	10	16.763	4.05	89.36	3.759
	12½	17.125	4.1	98.121	3.665
	15	17.113	3.9	111.424	4.238
	17½	17.125	3.45	109.338	4.272
44	7½	15.5	7.5	62.012	3.032
	10	15.693	7.3	85.236	3.228
	12½	16.175	7.0	85.544	3.575
	15	16.688	6.2	94.543	3.528
45	7½	16.413	6.5	57.865	2.315
	10	16.288	6.4	62.835	2.630
	12½	16.731	5.8	74.635	2.823
	15	17.475	5.0	97.269	2.970
46	7½	16.7	4.0	71.043	3.044
	10	16.75	3.8	84.785	3.636
	12½	16.888	3.7	87.444	3.621
47	7½	16.7	3.7	85.966	3.764
	10	16.875	3.7	94.128	3.889
	12½	17.125	3.1	115.933	4.666
48	7½	16.438	4.2	77.654	3.555
	10	16.425	4.2	88.885	4.083
	12½	16.738	3.95	98.116	4.184
	15	17.163	3.6	116.256	4.441

RAW DATA -- SJOSTRAND BICYCLE TEST ONE -- FEMALES

SUBJECT	HR1	HR2	HR3	KPM1	KPM2	KPM3	PWC170
01	118	136	173	162	350	697	670.684
02	117	143	173	171	363	548	533.089
03	125	145	176	195	432	671	628.794
04	115	141	155	180	360	540	648.350
05	132	155	187	180	576	941	729.870
06	118	136	155	180	348	531	672.423
07	123	161	173	174	548	722	670.185
08	103	136	170	174	576	941	948.955
09	91	120	155	183	548	894	1072.915
10	115	167	195	177	595	822	619.987
11	95	158	141	177	576	971	907.987
12	99	138	180	174	529	910	819.340
13	106	167	187	165	473	759	578.975
14	115	132	167	171	363	710	744.203
15	94	132	170	348	639	992	981.667
16	132	167	187	192	401	586	449.232
17	102	134	176	186	595	1018	965.002
18	113	132	167	280	522	874	914.170
19	129	155	180	171	576	672	624.213
20	118	161	180	177	558	747	649.326
21	97	130	170	168	522	889	924.304
22	101	136	167	183	567	941	969.078
23	101	130	155	177	548	697	875.486
24	85	129	180	165	520	817	764.984

RAW DATA - SJOSTRAND BICYCLE TEST TWO - FEMALES

SUBJECT	HR1	HR2	HR3	KPM1	KPM2	KPM3	PWC170
01	101	145	167	171	529	685	715.084
02	118	136	167	165	356	520	555.592
03	115	123	173	207	388	759	740.885
04	110	120	141	174	354	522	847.141
05	122	145	155	177	363	548	676.336
06	118	164	173	183	531	627	591.966
07	106	145	176	174	558	735	712.870
08	102	155	176	180	567	941	811.742
09	129	145	170	216	452	909	900.182
10	115	145	184	168	548	710	644.166
11	92	123	155	183	595	1018	1217.177
12	129	161	173	372	513	748	664.839
13	106	136	164	192	539	735	814.127
14	117	145	180	177	394	747	645.377
15	102	136	170	336	675	920	935.667
16	123	143	176	159	324	501	471.800
17	108	138	173	189	548	910	884.840
18	118	122	170	256	486	844	851.650
19	129	150	167	171	363	548	571.670
20	111	158	180	174	548	735	650.430
21	100	130	155	174	522	874	1052.088
22	103	134	167	177	558	925	966.077
23	89	132	176	174	548	864	827.293
24	90	127	164	174	558	735	814.986

RAW DATA - SJOSTRAND BICYCLE TEST ONE - MALES

SUBJECT	HR1	HR2	HR3	KPM1	KPM2	KPM3	PWC170
25	117	136	167	558	910	1365	1424.263
26	108	134	161	567	925	1365	1489.636
27	145	167	180	567	759	941	818.547
28	122	150	173	529	941	1278	1234.220
29	114	138	161	520	956	1321	1483.641
30	97	123	155	539	910	1504	1736.324
31	127	150	164	529	672	879	903.530
32	123	130	173	520	848	1278	1255.627
33	111	145	176	548	925	1430	1319.430
34	129	153	176	477	874	1181	1103.823
35	113	145	176	331	786	1126	1067.567
36	96	129	176	421	753	1330	1249.758
37	105	129	161	520	1075	1608	1806.684
38	123	150	173	722	1075	1658	1547.559
39	108	134	158	558	925	1278	1448.189
40	102	145	170	510	1094	1455	1449.409
41	96	111	153	539	848	1356	1606.773
42	110	129	170	520	848	1191	1214.341
43	95	113	130	520	894	1213	2011.415
44	106	132	167	558	910	1504	1536.323
45	155	180		833	1168		1034.002
46	129	161		510	817		903.344
47	110	129	158	595	1033	1386	1611.965
48	114	138	158	662	894	1409	1546.210

RAW DATA - SJOSTRAND BICYCLE TEST TWO - MALES

SUBJECT	HR1	HR2	HR3	KPM1	KPM2	KPM3	PWC170
25	129	150	170	558	941	1365	1354.632
26	107	130	161	548	925	1278	1417.213
27	148	173	187	567	659	971	738.717
28	117	141	167	567	941	1300	1351.032
29	111	136	158	558	941	1300	1485.184
30	107	136	173	576	1112	1685	1648.969
31	134	148	164	539	710	910	983.546
32	117	136	173	510	910	1321	1306.237
33	106	143	167	548	910	1343	1333.386
34	115	141	173	531	889	1244	1218.687
35	141	167	200	548	925	1321	940.036
36	101	150	187	513	1046	1427	1250.720
37	101	139	167	567	1213	1577	1652.876
38	118	141	173	722	1112	1658	1606.546
39	129	150	164	558	910	1278	1368.046
40	102	141	173	504	1046	1427	1400.679
41	118	136	170	735	1075	1630	1636.755
42	108	125	164	520	864	1170	1263.961
43	101	132	170	505	1131	1480	1521.320
44	108	132	167	548	941	1430	1483.808
45	125	164	180	539	879	1094	971.737
46	132	170	180	548	894	1094	945.643
47	107	132	161	548	879	1541	1575.395
48	115	141	158	624	925	1168	1307.646

RAW DATA - PROGRESSIVE STEP TEST ONE - FEMALES

SUBJECT	HR1	HR2	HR3	STEP1*	STEP2	STEP3	STEP170
01	129	158	176	4.23	7.28	8.68	8.23
02	136	158	176	4.23	5.63	7.28	6.72
03	145	161	187	4.20	5.60	7.31	6.12
04	122	158	176	4.20	7.31	8.71	8.25
05	155	170	180	4.20	5.60	7.31	5.91
06	132	158	184	4.20	7.31	8.71	7.78
07	148	176	184	4.20	5.60	7.31	5.75
08	125	161	167	4.20	7.31	8.71	8.64
09	129	145	173	4.20	7.31	10.11	9.94
10	138	161	176	4.20	7.31	10.11	9.00
11	129	158	180	4.23	7.28	11.51	9.69
12	123	167	176	4.20	7.31	8.71	7.92
13	127	161	176	4.23	7.28	8.68	8.12
14	143	161	176	4.20	5.60	7.31	6.64
15	115	145	173	4.20	7.31	10.11	9.82
16	150	167	184	4.23	7.28	8.68	7.12
17	120	136	170	4.23	7.28	10.08	10.32
18	129	158	173	4.20	7.31	10.11	9.38
19	123	132	161	2.82	4.23	7.08	8.12
20	145	167	176	4.23	5.63	7.29	6.39
21	123	150	167	4.20	7.31	8.71	9.16
22	113	129	173	4.23	7.28	11.51	11.34
23	141	167	195	4.23	7.08	9.88	7.31
24	101	132	173	4.20	7.31	10.11	10.02

* Step tests are measured in metres per minute with a stepping rate of twenty-eight steps per minute.

RAW DATA PROGRESSIVE STEP TEST TWO - FEMALES

SUBJECT	HR1	HR2	HR3	STEP1	STEP2	STEP3	STEP170
01	120	145	161	4.23	7.28	8.68	9.80
02	141	167	176	4.20	5.60	7.31	6.40
03	138	161	180	4.20	5.60	7.31	6.46
04	136	161	176	4.20	7.31	8.71	8.14
05	155	173	184	4.20	5.60	7.31	5.63
06	141	161	180	4.20	7.31	8.71	7.82
07	142	167	187	4.20	5.60	7.31	6.01
08	118	141	153	4.20	7.31	8.71	10.97
09	129	155	180	4.20	7.31	10.11	8.98
10	132	161	184	4.20	7.31	10.11	8.45
11	115	141	164	4.23	7.28	8.68	9.47
12	132	164	180	4.20	7.31	8.71	7.81
13	122	161	176	4.20	7.31	8.71	8.14
14	153	173	191	4.20	5.60	7.31	5.51
15	118	153	173	4.20	7.31	10.11	9.52
16	150	167	180	4.23	5.63	7.28	6.15
17	115	143	161	4.20	7.31	10.11	11.06
18	129	150	167	4.20	7.31	10.11	10.52
19	129	148	164	2.83	4.23	7.38	7.77
20	148	170	184	4.23	5.63	7.23	5.94
21	120	153	170	4.20	7.31	8.71	8.76
22	115	145	170	4.23	7.28	10.08	10.03
23	118	158	187	4.23	7.08	9.88	8.34
24	105	136	180	4.20	7.31	10.11	9.51

RAW DATA - PROGRESSIVE STEP TEST ONE - MALES

SUBJECT	HR1	HR2	HR3	STEP1	STEP2	STEP3	STEP170
25	134	153	167	7.28	8.60	10.08	10.25
26	107	136	161	7.28	10.08	12.91	13.76
27	161	180	187	7.28	10.08	11.51	8.67
28	155	170		7.28	8.68		8.68
29	145	155	161	7.28	8.68	10.08	11.48
30	98	115	158	5.60	8.71	12.94	14.53
31	153	167		7.28	8.68		8.98
32	103	123	143	4.30	8.71	10.11	14.61
33	117	148	167	5.60	8.71	11.54	11.65
34	136	170	184	7.31	10.11	11.54	10.23
35	141	150	167	5.60	7.31	8.71	9.19
36	141	167	184	7.31	10.11	11.54	10.25
37	130	153	161	7.28	10.08	11.51	12.55
38	150	161	167	7.31	8.71	10.11	10.42
39	122	145	161	7.31	10.11	12.94	14.02
40	127	161	173	7.31	10.11	12.94	11.97
41	138	161	170	7.31	10.11	11.54	11.43
42	100	141	170	5.63	10.08	12.91	12.98
43	138	161	176	7.31	10.11	11.54	10.96
44	148	155	167	7.28	8.68	11.51	12.14
45	129	150	167	7.28	10.08	11.51	12.01
46	130	173		7.31	11.54		11.24
47	118	145	155	7.08	11.34	12.74	15.11
48	122	148	176	7.31	10.11	12.94	12.34

RAW DATA - PROGRESSIVE STEP TEST TWO - MALES

SUBJECT	HR1	HR2	HR3	STEP1	STEP2	STEP3	STEP170
25	148	170	176	7.28	8.68	10.08	9.16
26	129	138	153	7.28	10.08	12.91	16.98
27	158	176	187	7.28	8.68	11.51	8.65
28	118	165	173	5.60	8.71	10.11	9.52
29	136	153	161	7.28	8.68	10.08	10.83
30	117	141	164	7.31	10.11	11.54	12.30
31	132	161	171	4.23	7.28	8.68	8.45
32	120	148	173	7.31	10.11	12.94	12.56
33	113	145	173	5.60	8.71	11.54	11.22
34	132	158	180	5.60	8.71	10.11	9.40
35	125	161	173	2.80	7.31	8.71	8.37
36	130	161	187	7.31	10.11	11.54	10.45
37	132	145	158	7.28	8.68	10.08	11.37
38	134	148	164	7.31	8.71	10.11	10.70
39	127	143	155	7.31	10.11	12.94	15.77
40	125	153	173	7.31	10.11	12.94	12.40
41	127	155	170	7.31	10.11	11.54	11.56
42	141	170	184	7.28	10.08	11.51	10.11
43	118	141	158	7.08	9.88	11.34	12.76
44	134	145	155	7.28	8.68	10.08	12.06
45	136	161	176	7.28	10.08	11.51	10.93
46	127	173	173	7.31	8.71	8.62	8.62
47	127	155	170	7.08	11.34	12.74	12.98
48	114	145	167	7.31	10.11	12.94	13.06

